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NOTES ON THE GEOLOGY AND GEOGRAPHY OF THE BAGUIO MINERAL DISTRICT.

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(From the Division of Mines, Bureau of Science, Manila.)

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SUMMARY.

INTRODUCTORY.

Benguet and some portions of adjacent northern Luzon have been visited and explored by numerous scientists and travelers and in addition to the interest which the region and its inhabitants have aroused, the undoubted occurrence of gold, apparently in considerable quantity throughout the region, has increased the desire for more knowledge of this part of the Philippine Islands.

Almost since the day when Spain released the Islands to the United States, prospecting and development of the mineral resources of the country has gone on and confidence in its value has steadily increased. With that confidence, active operations have gradually expanded and at this date, the mineral wealth of the Philippines seems to be assured. The Benguet district in particular may be ranked as one of the most promising of the Islands.

The investigation of which this report is the result was begun by me in April, 1905, and attention was first turned to a topographic map of as much territory as seemed to be under immediate development. Mapping was carried on over the area covered by mineral claims and this ground was extended also to take in that area in which the study of the geologic and related problems would seem to have a bearing on the purely economic questions involved. With the assistance of one American and occasionally a few Igorots, the map work was completed by the beginning of the rainy season in June. The area embraces about 100 square miles including, in addition to the work of the writer, a survey of the Bued River cañon, made by Major *L. W. V. Kennon*, United States Army, when he was in charge of the construction of the Benguet road; and a topographic survey of the immediate vicinity of Baguio by Mr. *G. H. Guerdrum*, assistant engineer of the Bureau of Public Works, in charge of Baguio surveys.

Stadia work with a transit based on a system of triangulation of the most prominent points and checked by traverses and rapid reconnaissance methods such as were consistent with the accuracy required, were employed to accomplish the work in as short a time as possible. The map, which is published with the report, includes the region between Mount Santo Tomás on the west and the limit of mining or prospecting operations on the east; from near Trinidad on the north to a little south of Kias or "Camp Four" of the Benguet road on the south. In November, 1905, the field work was resumed and the investigation of the geology and mines taken up during a field season of four months.

The latter work, which I carried out alone, only using native labor in transporting specimens, etc., was undertaken first with headquarters at

Baguio, from which point at least the more elevated portions of the area could be reached by aid of a horse. A general geologic reconnaissance of the district extending beyond the mapped area, in order fully to grasp certain broader problems was followed by a more detailed study of the geologic relations of the smaller area. The perhaps extraordinary occurrence and sequence of geologic phenomena in so limited an area made this portion of the work extremely interesting, and, needless to add, correspondingly difficult.

Within a comparatively limited field, the study of recent vulcanism reveals lava flows of different ages, igneous intrusions of notable extent and the still active evidence of numerous hot springs; ore deposits are encountered of undoubted value and extent, varying in type from free milling gold ores to "basic" gold-bearing sulphides of copper, lead, zinc and iron; sedimentary beds with a rich fauna can be seen, the study of which may be vitally important to broader questions of the former extent of the Philippine Islands, or rather their connection with continental areas; rarely can such a combination be found, both as to the interest to the scientist and the value of knowledge to be gained from an economic standpoint.

With the information acquired by me, the way was clear to a closer study of smaller areas from a purely economic basis. It was possible by camping at the different places where prospecting and mining operations were going on thoroughly to examine every opening of importance. Ores and veins were inspected, faults measured—in short, all that was necessary was done to attain the total of information, so far as it might be derived from the present stage of the district in mine development. Numerous samplings and assays aided in the work, and in addition some underground surveys were made where vein structure or dislocation made it advisable.

In the field, excepting in rare instances, every assistance and coöperation was met with. The natives, miners and others with whom it was necessary and desirable to come in contact made smooth many rough paths, and this brief acknowledgment of those courtesies and aids may be taken as but a fraction of the appreciation of the writer.

It is a pleasure to record the aid of my colleague Mr. W. D. Smith in determining and classifying the fossil remains of this region while I was studying and working on field material during the preparation of this report, and in that connection no little coöperation was rendered by him in aiding me to an understanding of the paleontology and the petrography of the region; this will be spoken of later. I also desire to express my appreciation of three weeks' assistance in the field given me by Mr. Smith.

GEOGRAPHY.

POSITION.

As has already been stated, the area mapped and discussed in this report embraces about 100 square miles, of which Baguio, although near the northern boundary of the area, is the logical center. From Baguio radiate such roads as the region possesses, and like any other, the development of transportation precedes or parallels development along all other lines.

Baguio is the seat of government of the entire Province of Benguet; its location is given in the Gazetteer of the Philippine Islands for 1902 as approximately in longitude 120° 38′ 50″ E. and in latitude 16° 32′ N. Later observations give exact figures as latitude 16° 24′ 27.14″ N. and longitude 120° 36′ 6.9″ E., making the site of Baguio somewhat less than 150 miles almost due north of Manila.

TRANSPORTATION.

Baguio is reached from Manila from both the south and the west, as will be seen by reference to the map showing transportation routes of the region. At present, Dagupan is the "farthest north" as far as rail transportation from Manila is concerned, but preliminary work is well advanced for the continuation of the railroad through to Camp One on the Benguet road. The western coast of Luzon is also marked by a railroad route, and a few years more will see it in operation. From the western coast and the foothills at Camp One, a horse trail and an automobile road respectively terminate at Baguio. The mineral region lies to the east of the Benguet road and that region will be spoken of in this report from now on as the "Baguio district." Prospecting or mining has been done to a more limited extent outside of this area and so little definite information has been gathered, that for all purposes "Benguet," as the miner speaks of it, is translated into the plateau region extending easterly from the eastern slope of Mount Santó Tomás and lying partly on the elevated plateau or ridge which is a portion of a northwest-southeast range of considerable extent, and for the remainder and greater part including the headwaters of those rivers which have cut laterally and transversely into the main mountain mass.

In this region transportation is generally by trail. On the upper and more level portion of the area, and especially in the vicinity of Baguio, considerable road work has been done. Between La Trinidad and Baguio a good wagon road has been constructed, the southern continuation of which has been carried to Loacan and the Copper King mine. A wagon road has been built to Bua from Baguio over which the Benguet Consolidated Mining Company hauled the mill recently installed. In the region set apart for a summer colony near Baguio, numerous drives have been laid out.

Well-graded horse trails have been constructed from Kias to Baguio, around the east flank of Kias Ridge, and from Bua to Itogon. There is some form of trail between all the pueblos and barrios of the district, and the present governor of the province is carrying on excellent work in the construction of new and the repair of old lines of communication.

Freight for Baguio can be handled via steamer to San Fernando, on the west coast of Luzon, and thence to Baguio over part of the distance (to Naguilián) by road and the remainder by pack train, a total distance of about 25 miles from the coast; or, as at present, via rail to Dagupan and from Dagupan to Baguio over the Benguet road. The distance from Dagupan to Baguio via the Benguet road is 53.54 miles, of which the distance to Camp One is 26.2 miles over flat grass country. The construction from Camp One on is that which has attracted considerable attention, principally because of its high cost—$75,000 per mile, or a total of about $2,500,000 to the date of nominal completion.

The first survey of this road was made late in 1900 and an estimate of $75,000 for cost of construction given. Various causes contributed to the delay in completion and the increased cost, and it was not until January, 1905, that it was possible to make the through trip on wheels. As many as 2,500 laborers of almost every nationality were employed at one time on the construction work, native Filipino labor being extensively used. An elevation from sea level at Dagupan, and a slight elevation at Camp One, to 4,800 feet at Baguio is gained in its 50 miles of length with an actual maximum grade of 10 per cent. Whatever the cost (and although maintenance costs will be heavy) the road supports traffic and furnishes the only real highway to the Baguio district.

The route from Baguio to San Fernando is perfectly feasible for cheap wagon-road construction and when the coast railroad is completed to the latter point, the coast route may seriously compete with the Benguet road either by wagon or railroad extension. Present freight rates from Manila to Baguio are as below:

Manila to Dagupan, rail, 41 cents (Philippine currency) per 100 pounds.
Dagupan to Baguio, wagon 3½ cents (Philippine currency) per pound.
Manila to San Fernando, steamer, ₱6 per ton of 40 cubic feet.
San Fernando to Baguio, packing, estimated ₱3 per 100 pounds.

The cheaper route is, therefore, via Dagupan, and of course it is quicker. Passengers can go through in twelve hours from Manila via rail and automobile. The railroad to Camp One will cut time and prices, and beyond occasional washouts, etc., which are to be expected, the Baguio district will at the close of 1907 have a reliable and rapid method of communication with Manila.

From Baguio, the transportation problem is one of small magnitude. The Copper King region is reached by an almost level wagon road which needs little expense for maintenance. Bua is reached by a wagon road of a maximum grade of 6 per cent, and trails and roads to the Antamok

and Gold Creek region are easy and cheap of construction and maintenance if properly located and built in the beginning. Wagon transportation is perfectly feasible to any part of the mineral district. Repairs will not be excessive, provided proper ditching is done and culvert work is constructed and the torrential rains of the summer are taken into account; and such small bridge work as is necessary can be done cheaply with the abundant standing timber and cheap native labor.

CLIMATE.

The climate of this region has been much discussed because of the proposed use of Baguio as a summer capital, and as a convalescing station for the United States Army, Navy, and the Civil Government employees of the Philippine Islands. Briefly summarized, from various reports of the Weather Bureau, the following may be stated:

The temperature, taken at Baguio and representative of all the Baguio plateau, is on the average consistently lower than that registered at Manila by 7° C., the difference ranging between 7° and 9° C. throughout the year, as is shown by the following table, which is a plot of the temperature variations at Baguio and Manila, recorded during 1900 and 1901.

The daily variation ranges from 2.4° C. to 8.7° C., the changes being quite in inverse proportion to the rainfall and increased cloudiness.

Variation of the temperature at Baguio and Manila for the years 1900 to 1901.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Manila	25.25	25.15	26.7	28.4	29	28.3	27.5	26.9	27.5	27.2	26.5	25.4
Baguio	17.45	16.8	19.35	21.35	20.15	19.5	19.15	18.15	19.4	19.6	18.9	17.95
Difference	7.80	8.35	7.35	7.05	8.95	8.80	8.35	8.75	8.1	7.6	7.6	7.45

The minimum temperature both in Manila and in Benguet is reached in February, with a second minimum in August, due to the extraordinary rainfall which occurs in that month. From February a steady rise occurs, which culminates in a maximum of about 29° C. in April, the warmest month, followed by a steady decline to the end of the year, only broken by the August depression, with a reaction of about one degree in September.

The annual rainfall, considerably more important than the temperature, amounting to over 100 inches per annum, places the Baguio district under the classification of the regions of abundant rainfall. The year is divided more or less distinctly into a dry and a rainy season. The salubrious climate of the region, at least during the dry season from February up to and including June, is principally due to the rainfall conditions. As there is no high land on the east and south, the prevailing winds during these months, from the west and southwest, cause a moderate rainfall, thereby reducing the temperature during March, April, May, and June.

PLATE I. TYPICAL TIMBER STAND ON BAGUIO PLATEAU.

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Rainfall for 1900–1901 at Baguio, in millimeters.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.49	14.46	37.08	8.11	102.11	318.52	391.93	940.33	288.66	125.70	64.00	138.77

Total, 2,431.16 millimeters = 96.23 inches.

During the same period the rainfall at Manila amounted to an average of 1,986 millimeters.

From September, 1902, to August, 1903, observations were as below:

Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
602.7	212.1	75.9	24.1	5.1	0.0	16.5	97.0	131.8	168.4	760.8	767.9

Total, 2,862.3 millimeters = 112.77 inches.

Care in road construction is one of the principal necessities caused by rainfalls of such magnitudes as are recorded, and the drainage in the streams creates a problem of control to be considered wherever water power is used. During the rainy season, and especially after one of the heavy rains of a few hours' duration, where 20 inches or more may be recorded in a day, streams which have been but threads of water become rivers of great velocity and power for harm.

VEGETATION AND TIMBER.

Open grass land and areas of pine timber constitute almost all of the Baguio district, with the grass lands predominating; an almost insignificant percentage of agricultural lands also exists. A thick stand of cogon grass of 2 or 3 feet or more in height, which is burned during the dry season, is on the open grass land, and these areas are the cattle ranges of the country.

The timber is practically all pine, of one species (*Pinus insularis* Endl.); it resembles the loblolly pine of the southern United States very closely in size, form, rate of growth and character of wood; when it is on the upper slopes and ridges in more open and exposed stands, it is very similar to the western United States yellow pine. The forest is quite open, with heavier growths along streams, north slopes and other sheltered locations. Here the timber attains its best height and growth. Some hard wood occurs, but it is negligible in amount, except on the summit and west slopes of Mount Santo Tomás.

The timber will average about 100 feet in height and in diameter 21 inches, giving a merchantable length of 57 feet, with four logs with a yield of about 550 to 750 board feet per tree, or as measured on a given area, a cut of about 2,300 feet per acre, the entire stand amounting to 7,500 feet per acre.

One company has been taking out timber for local use with a small mill and native labor; the wood which up to the present has been used for building construction was of sapwood (*Alburnum*) and unseasoned; it has shrunk and warped badly, but it is believed that with proper seasoning it will give satisfaction. The sapwood, yellow white in color like the loblolly pine, rots too readily in contact with the ground, but the light, red-brown heartwood, is more durable it is frequently very resinous, and when so, is practically indestructible.

For mining purposes, there is sufficient timber within every distance to satisfy demands for some time to come for a camp of moderate size, and with a greater growth of the mineral industry, logging can keep pace with development at a reasonable expenditure.

Agriculture in the district is confined to a very small area and only a sufficient amount for local consumption is produced.

The population of the Baguio district proper only embraces two or three barrios of small size. Benguet Province has a population (census of 1903) of 22,745, of which 917 are civilized and 21,929 "wild;" that is, Igorots. The civilized population which is congregated almost entirely in Baguio and La Trinidad, consists of Ilocanos, with a sprinkling of other coast races. The total population, of which about one-half or approximately 11,000 are males, with possibly another 9,000 from surrounding provinces, represents a body of not over 20,000 males to draw on for possible labor. "Possible" is used advisedly, for of this number, because of condition, location, aversion to work, etc., it is not believed that more than several thousand are to be considered in any way as "probable" labor. The Igorot of these parts at least is a mild-mannered brown man, small in stature, but well endowed physically, whose wants are infinitesimal. Experience with him as a laborer has demonstrated his usefulness to a degree. A considerable number of the race are quite familiar with crude mining operations and are fair workers underground. They are fairly intelligent, peaceable and good, natured, and when for some cause they are driven to labor, are—in view of their low rate of wage (25 cents, gold, per day) and efficiency—satisfactory, unskilled laborers. Anything beyond that can not be looked for and moreover there are but few of them who will remain in employment for any length of time.

HYDROGRAPHY.

Probable nowhere in the Philippine Islands is the work of rain and running water so clearly indicated as in the Baguio district and vicinity. Changes take place in the surface of the area; drainage shifts, and the topography alters almost visibly from day to day. The drainage of the region is noteworthy.

PLATE II. AGNO RIVER VALLEY NORTH OF AMBUKLAO.

PLATE III. THE ANTAMOK RIVER VALLEY

DRAINAGE.

Although the Agno, the largest river of the Province of Benguet, is beyond the border of the district to the east, it has an important bearing on the drainage. The headwaters of this river are on the eastern flank of Mount Datá, the divide between southern Lepanto and northeastern Benguet, and in its passage south to the plains of Pangasinan it gathers the run off from the western slopes of the main mountain range, the *Cordillera Central*, the backbone of Luzon, and the eastern slopes of the smaller range and ridge which forks southwesterly from Datá and terminates at Santo Tomás, forming the Benguet highland. Therefore, it gathers meteoric waters over a comparatively large area, and erosion by it and its tributaries has been considerable. All the drainage from the eastern half of the Baguio district feeds into one branch, the Itogon.

The Antamok River drains the smaller valley east of the Pakdal-Itogon Ridge; it is quite dissimilar to the rest of the drainage in that it possesses no tributaries of any magnitude. Although the valley has been deeply incised, no lateral streams have kept pace with it within the map limits. At its headwaters east of Pakdal there is more or less of a basin of auxiliary drainage; at Bua, one small western branch is developed, and east of Antamok a somewhat larger branch to the north has cut into the eastern wall of the valley, but erosion has generally been confined to the main valley. Some rough measurements on the Antamok in the dry season gave the quantity of water flowing as 1,200 cubic feet per minute, or 20 second-feet. Power is being taken from the river at this point for use in a stamp-mill and developed by pipe line and impulse wheel.

A short distance below Antamok, the Antamok River joins the Itogon, of which it is a lateral tributary. The Itogon drains the area from the Pakdal-Itogon Ridge to the Kias Ridge, through several good-sized streams and through the Sile or Gold Creek, the Batwaan and many smaller streams. Gold Creek has the larger territory, heading in the eastern and southern sides of the Baguio Plateau and reaching the Kias Ridge with its eastern branches. Its volume normally is greater than that of the Antamok, and throughout its area the lateral branches have kept pace with the erosion of the main channel, cutting a well-defined basin between the Kias and the Pakdal-Itogon Ridges.

The Batuaan heads in the southern end of the Kias Ridge and again resembles the Antamok in its clean-cut valley with little lateral extension. The system described above constitutes the drainage of the larger and eastern part of the Baguio district.

The Baguio Plateau is drained to the north and west directly to the China Sea, via the Irisan and Trinidad Rivers, which in the Baguio district proper are mere creeks, cutting slight valleys in the plateau.

Their work has been different from the erosion of the southern portion of the area and except for the drainage purpose they serve, they are unimportant. This will be further discussed under physiography.

On the western side of the Baguio-Kias Ridge, the Bued, or Moti River is the channel through which drainage proceeds. The origin of the Bued is not far from Baguio, on the plateau, and after collecting the waters of the elevated regions, it cuts its way, between Mount Santo Tomás and the Kias Ridge, south to the plains. Laterals tributaries are numerous, and some of them, like the Balatok Creek at Kias and the large tributary (the Quisat, in the native dialect) coming in east of the crest of Santo Tomás, have in erosion almost kept pace with the main stream. The Bued River cañon is the most noteworthy in the district. Cut in a gentle reversed curve from the edge of the Baguio Plateau to the debouchement on the plain below at Caoriugan, and in depth over 2,000 feet to the bed of the stream, this gorge is opened up by the Benguet road on its lower slopes, where formerly travel was well-nigh impossible, the old Igorot trails being on the ridges on either side.

Viewed from the standpoint of possible water supply, the region is well watered, even in the dry season. Numerous large and pure streams, enough to supply a population as numerous as will probably ever occur on the Baguio Plateau, exist there. The district throughout is well supplied with potable water, and, although by the arbitrary map boundaries, certain hot springs do not fall within its lines, it may be well to mention them.

MINERAL SPRINGS.

Large sulphur springs which have been used for ages for medicinal purposes by both natives and others in the country are found in the lower part of the Bued River cañon, a half mile or so below Balongabong or Twin Peaks, on the west bank of the river. These springs have a temperature of about 50° C. and are distinctly sulphurous. Other smaller and similar springs may be noticed at various places along the river above.

On the Itogon River just outside of the eastern boundary of the map of the district accompanying this paper, is a group of hot mineral springs which have formed deposits of considerable extent. The water in these has a temperature of about 86° C. and in several of them distinct geyser action, with an intermittent flow of some force, is noticeable. The springs are saline and some of them contain sulphuretted hydrogen gas. The most noteworthy constituents of the water, by analysis, are: carbonic acid gas, sodium chloride, sodium and calcium sulphates, silica, calcium and iron bicarbonates and nitrogen, a total of about 2.5 grams of salt in solution in a liter. The spring is claimed to be very beneficial for medicinal purposes and it could well be utilized by proper construction, as it is less than 10 miles from Baguio.

North of the Baguio district, at Tublay, hot springs also exist of the same general character, but slightly lower in temperature (70° C.) and containing a smaller amount of salts in solution. Iron springs, now apparently quiet, have left large deposits in the vicinity of Bua, and in various other localities hot-spring action is plainly indicated.

The northern part of Benguet Province is particularly richly endowed with mineral springs, hot and cold, and the geology of this and adjacent regions clearly indicates, geologically speaking, the evidence of only recent vulcanism, or more strictly, its final and dying phenomena.

PHYSIOGRAPHY AND TOPOGRAPHY.

The Baguio district—that is, the region covered by the topographic map accompanying this paper—is a small portion of a part of northern Luzon, with which it is very closely connected and of which it is representative; it so happens that this small region is immediately on one of the main tectonic axes of the Philippine Islands, and hence of the Malayan Archipelago. The *Cordillera del Norte* situated a few miles to the east of Baguio is the main axis, at least of the western half of northern Luzon. The mountain system of Benguet, on the southern end of which the Baguio district is located, is only one of the many ramifications of this master axis, which has its origin on the east side of southern Luzon and which may safely be continued to east Mindanao. This major axis is probably one of the original tectonic axes of the Asiatic Continent, formed by the wrinkling of the more plastic crust of the earth as the globe has contracted. In it the oldest of the Philippine rocks are found and on it all of the agencies of construction and destruction have been at work since the Philippine Islands, as such, originated.

Throughout the Province of Benguet there runs a subsidiary chain, the two ends of which are established by Mount Datá on the north and by Mount Santo Tomás on the south; this range, or more strictly speaking, this ridge, describes a curve, concave to the east.

The Agno River, cutting its valley, which originally was a purely tectonic depression, between the Benguet Ridge and its main trunk, the *Cordillera,* has incised its main valley so deeply and has, by erosion of its tributaries over its catch basin, removed such an amount of material to the plains lying toward the south, that the Benguet Ridge stands out as a mountain range, small but fully developed, between the coastal plain along the China Sea and the *Cordillera Central del Norte,* the backbone of Luzon, with a large valley, that of the Agno River, separating them. The mountain region of Benguet then, of which the Baguio district is representative, is of this simple type. It represents no diastrophic change of the earth's crust, as the "block" type of mountains in which huge blocks of strata have been uplifted along a fault plane and tilted into prominence, as is the case in the southern

Oregon (United States) ranges and is true of other parts of the Great Basin region of the United States, nor does it represent the folded type of which the Alps are the most familiar example; huge folds and overturns of strata like crumplings of so much paper. The strata covering the east and west flanks of the Philippine mountain areas have been gently raised and broken, leaving the ends of the arch on either side, but a part of this tilting was due to the formation of the sea deposits on the already inclined floor of the mass where the ridge has been produced; moreover there has only been comparatively gentle arching.

PHYSIOGRAPHIC DISTRICTS.

Beginning with a small region which locally represents such a simple type of elevated country, there is developed within it four distinct physiographic types:

(1) The mountain region.
(2) The elevated plateau.
(3) The intermediate uplands.
(4) The incised-valley system.

THE MOUNTAIN REGION.

The mountain region is barely represented. The eminence of Pakdal is a remnant, no doubt, of the original ridge which ran north at an elevation of probably over 6,000 feet, to join the higher region of northern Benguet. It stands up from the eastern edge of the Baguio Plateau to a height of about 5,500 feet, and though seen from the west its elevation is not particularly noteworthy, the absence of the plateau on the east reveals the height of this region in the drop-off to the valley of the Antamok River and in the unobstructed view of the Agno Valley and the main *Cordillera* to the east from the top of the ridge.

Mount Santo Tomás on the other hand is a part of the "mountain region," but it is so only because of its height. It is not, as is Pakdal, a remnant of the former configuration. Santo Tomás is a block mountain of the faulted type and it is locally developed, being the only instance of such development in the Baguio district. A fault scarp of about 1,500 feet marks the northeastern slope, which is closer to a vertical than to a horizontal plane. The tilting of this large block of sedimentaries is plainly to be seen from the Bued River side of the Baguio Plateau and the corner of the block—the crest of Santo Tomás—at 7,342 feet above sea level, is as sharply defined as it could be pictured. Because Santo Tomás is on the edge of the plateau the height is more apparent from the south and west, where the slopes of the mountain run down to the coastal plain. From the plateau side, where there is a difference of elevation of less than 2,500 feet, this height is not as noticeable.

Typical mountain topography prevails on both these eminences (Santo Tomás being included, although abnormal). There is but little good water, almost none in fact, at these elevations, standing as they do clear of all the surrounding country; consequently all erosion is a direct result of the very considerable rainfall of 100 to 120 inches per annum. Denudation has been rapid, especially on Santo Tomás and deep scars have been cut into its flanks by the erosion of the streams carrying the run-off. All the streams are naturally far above base level, and deep, V-shaped gorges represent the type of stream beds. While frost is rare here, the difference in temperature is sufficiently great, no doubt, somewhat to aid in the disintegration of the rocks. Steep slopes prevail, and talus is carried away by the excessive erosion, so that sharpness of outline continues to exist.

THE ELEVATED PLATEAU.

The Baguio Plateau is the most striking of the four physiographic types of the region. It is a peneplain of limited extent, with an average elevation of about 5,000 feet and with a drainage and topography so characteristic of a lowland region, that, viewed from a central point where the valleys of the Bued and Agno River drainage are not visible, it is hard to realize the situation of the area.

The drainage is not deeply marked and there is plain evidence of much shifting of divides and valleys. Only small streams prevail over the region and except for transitional border areas where gradients are increased very rapidly before the streams drop off into the deeper valleys, the erosion has not been great in stream beds. Baguio proper drains to the north into the Irisan and Trinidad Rivers. The Pakdal area divides its drainage between the north, uniting with that from Baguio, and the southeast, draining into the deeper valley of the Agno tributaries. There are no streams of any size in this portion of the district and the large rainfall seems to be partly added to the ground water and partly run off in numerous small channels, rather than through any well defined system.

South of Baguio and Pakdal the drainage is to the east and west of the Baguio-Kias Ridge, into both the Bued and Agno waterways. The topography is of a mature type over the entire region. Low, rounded hills with gentle slopes, graded valleys with low gradients and in part winding streams which show some small amount of rejuvenation in the more deeply cut valleys exist, but they have not altered the serpentine course they followed originally. The stream draining Baguio affords one instance of this character. It is a barely noticeable brook from the divide where it originates up to a ponding which occurs south of Baguio; the softer rock materials here have yielded to erosion and the stream, although formerly large and flowing directly from the depression through

a now deserted wind gap to the north, has barely sufficient gradient to join the Pakdal drainage to the east of Baguio, where a small, well-defined valley, with slopes and a gradient out of all proportion to the remainder of the drainage back of it, joins with a second flattened area north of Baguio. From this it finally escapes into the Trinidad River.

The headwaters of the Pakdal are merely rivulets which follow such valleys as they have themselves been able to cut during the seasonal rains, and in many instances the shifting of the local divide for a few feet has resulted in the capture of adjacent streams and the abandonment of the older channels.

The Pias Valley is more marked and although it is relatively of small size, it has rounded out a fairly mature existence before it drops off into the Bued River channel west of Laoacan. At Laoacan another old valley, now devoted to the cultivation of rice and which has a small stream flowing through it, is evidently a relic of the former drainage of the region. This valley is mature and almost devoid of running water; at its mouth it drops off through a declivity of almost a thousand feet to the valley of the Bued River.

The drainage of the whole plateau is striking in that in itself it exhibits every evidence of maturity and that only the corrasion of the near and the more powerful superimposed drainage has thrown it into relief, at an elevation of 5,000 feet and over.

THE INTERMEDIATE UPLANDS.

The intermediate uplands are represented by the drainage of the Bued and Agno River tributaries. The elevation of these regions ranges from 2,500 to 4,500 feet, and as they are evidently confined to one period, they are normal in every particular; with the valleys of the Antamok, Batuaan and Gold Rivers and their total drainage area, the intermediate uplands and the valleys they constitute one region, all lying to the east of the Baguio-Kias Ridge. A comprehensive view of the region from either the Pakdal or Kias elevation shows that the central valley, namely that of the Gold River, is the more mature. The Antamok and Batuaan streams have confined their work to the cutting of steep-walled valleys with few lateral tributaries; their slopes are steep, with a gradient generally of over 30°, and both streams maintain a fairly direct course. Their headwaters are basin-like in character and in these situations erosion is pronounced. The Gold River has been widened to a greater extent by lateral tributaries, and it presents a valley broad enough and sufficiently graded to support several small villages with their attendant industries, agriculture and the raising of cattle.

PLATE IV. BAGUIO.

PLATE V. LAOACAN, SANTO TOMÁS IN THE BACKGROUND

Plate VI. VALLEY OF THE ANTAMOK RIVER BELOW ANTAMOK

PLATE VII. BUED RIVER VALLEY.

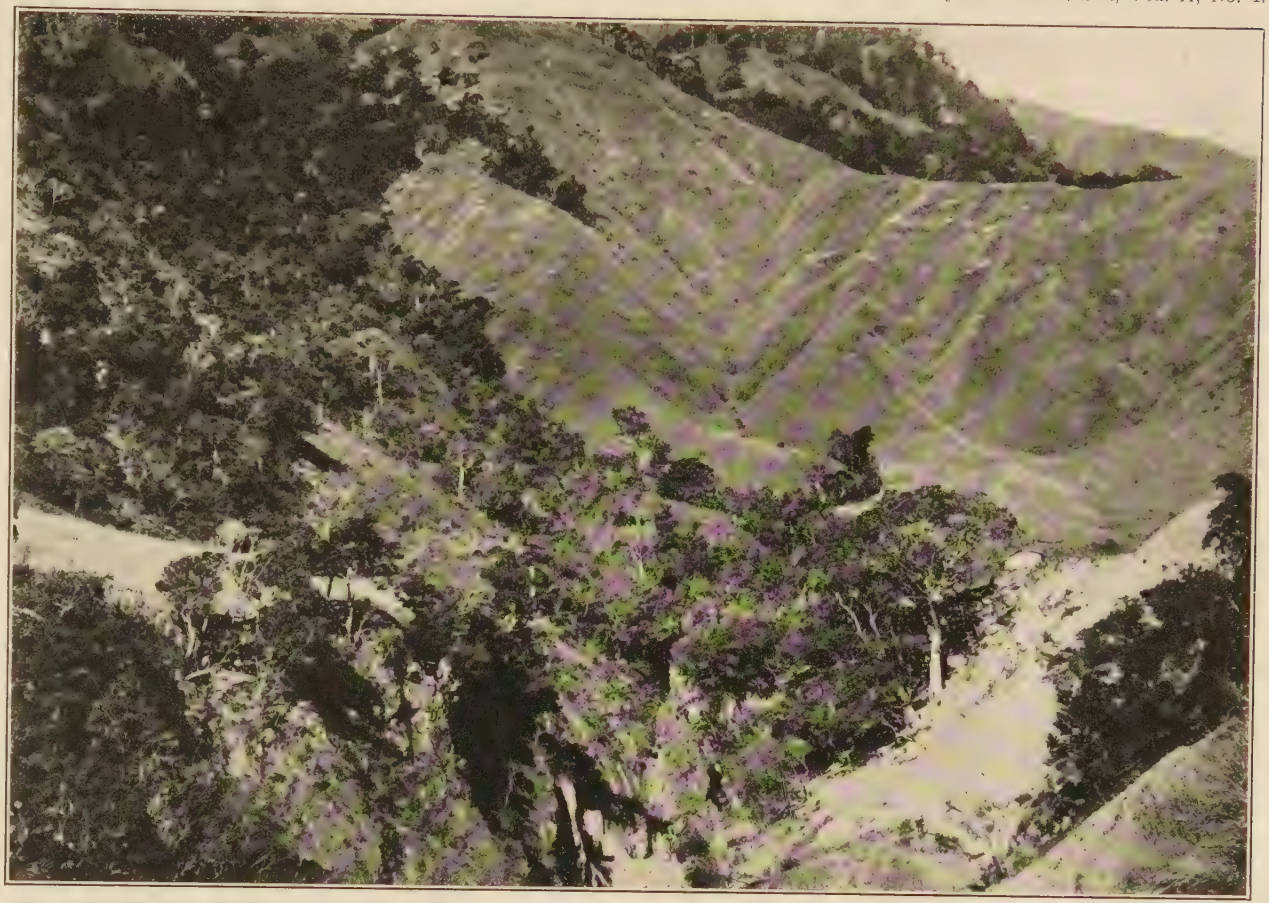


PLATE VIII. LOWER SLOPES OF THE BUED RIVER AT KIAS.

THE INCISED VALLEY SYSTEM.

As has been stated before, the Bued Valley is noteworthy for its beauty and grandeur. Its side slopes will average much over 30° and in that portion of it covered by the map, it gains an elevation of from 2,000 to 5,000 feet. In the transverse section there is evidence of several stages of deepening and at Kias there is pronounced evidence of recent uplift, tilting from the south; nowhere is the V-shaped gorge sufficiently wide at is bottom, nor sufficiently gentle of slope to support more than an Igorot hut or two, and it is only since the construction of the Benguet road along the valley that it has been the scene of human activity. Hanging valleys are common along its course and the entire evidence of topographic forms tends to the conclusion that the drainage has been of more recent origin than that of the Baguio Plateau. It is especially evident that this is the case where lateral gorges enter the main valley, and at the southern end of the valley the present stream is cutting at a rapid rate vertically into its V-shaped cañon.

GEOLOGY.

GENERAL.

Although the Baguio district is but small in area, there are involved in it geological problems almost too broad and complex to be within the scope of this reconnaissance. Such data as have been gathered, and which will have to serve until a study may be made of a more extended field, will be subject to greater or less modifications in the light of future work. Beginning with the oldest rocks, we have a basal mass composed of dioritic rocks which can be correlated with, and evidently is, an integral part of the dioritic base exposed in Lepanto and in other northern provinces of Luzon. Excepting certain local variations of composition and texture, these two rocks are petrographically identical, and the stratigraphic evidence is all on the side of the hypothesis of a dioritic igneous core, of at least this one (Luzon) of the Philippine Islands. It has been taken for granted by a number of the few who have heretofore written on Philippine geology on such evidence as was available, that the hidden core of the Philippine group would eventually be found to consist of crystalline schists upon which post-Tertiary sedimentaries have been laid down and to which mass the neo-volcanics have been added, but so far, at least in northern Luzon, the areas seen have uniformly exhibited a massive dioritic base. Becker[1] has carefully summarized all the occurrences of schists and older rocks of the

[1] Report on the geology of the Philippine Islands, *U. S. G. S. 21st. Ann. Rep.* (1899–1900).

Archipelago which were known at the time his paper was written, and while he points out that there may be a more or less close connection between the Philippine group and Borneo on lithologic grounds, he admits that there is no inconsistency in Abella's view [2] that the dioritic rocks represent the oldest of the Philippine series, if those schists of similar composition are included under the head of "dioritic rocks." It is a pleasure to record in the results of work even so little detailed as that given in the present paper, data which coincide with the deductions of Mr. Becker, who had only vicarious observations of varying reliability to serve as criteria and also with the observations of Abella, who, although limited in his scope of work, has proved, for the most part, to be the most trustworthy of the workers in this field.

BASAL MASS.

There seems then to be good ground for believing that the diorite I have observed in the Baguio district represents the starting point of our Philippine geology, at least for northern Luzon. I have described it in a former paper,[3] discussing its appearance in Lepanto; it occurs over a large area of the present Benguet field; various observers have noted it over a sufficiently large portion of Luzon; and Abella in particular has verified his field notes with the microscope in order to justify the above hypothesis.

In the Baguio district the exposures of the basal diorite, as would naturally be supposed, are generally most prominent at the lower elevations, although on the western border of the area, the most prominent exposure is the highest point in the district, namely the crest of Mount Santo Tomás. Here the rock is light green in color, finely grained, holocrystalline to the eye, hard and compact, with apparently little weathering. Plagioclase and amphibole may be distinguished with a lens, together with some chlorite and occasional quartz and magnetite crystals. The valley of the Antamok River shows the best exposures of this diorite and it is here most typical of the large area.

The rock megascopically is dark green, holocrystalline, massive; it is very hard and apparently more resistant to erosion than any other rock in the district. Only plagioclase, amphibole and a dark-green chloritic mineral can be distinguished with the eye. Locally, over a small area, the amphibole is developed to a greater extent. At one of the tunnels of the Bua Mining Company, the main cross-cut to the "main reef,"

[2] Abella: Apuntes físicos y geológicos (1884), 30.

[3] Eveland: Preliminary Reconnaissance of the Mancayan-Suyoc Mineral Region. *Bull. Min. Bur.*, Manila (1905), 4.

the porphyritic nature of the rock, which has amphiboles sometimes measuring 15 millimeters in length, is very evident. In connection with the development of the amphiboles, the almost universal quartzose nature of the rock is less evident or entirely wanting—no quartz can be seen with the eye or with a hand lens. Under the microscope the normal phase of the basal diorite presents a granitic or a pan-idiomorphic granular structure. In almost all the sections examined much saussuritization has taken place and the resultant minerals are variable in different localities. The structure is plainly that of a plutonic rock and there is evidence of slow cooling, the first crystallization taking place being that of the feldspars. Certain sections show porphyritic facies and the mass is evidently variable. The plagioclase feldspars show polysynthetic twinning, and in these sections they are probably near the lime end of the series, calcite being pronounced. Possible intergrowths of feldspars are noticed. Measurement of extinction angles on different sections in some cases gives labradorite (observed on Carlsbad twins); other sections at right angles to the albite twinning gave 31° to 33° as extinction angles. A slide occasionally shows anorthite, and a sample of the rock from the valley of the river Sili exhibits andesine.

The feldspars are much decomposed, and calcite, zeolites, epidote, and chlorite are present in varying amounts. The ferro-magnesium minerals generally are too much decomposed to show more than outline of faces, but from occasional fresher sections they are clearly determined to be pyroxenes. Actinolite has evidently been a constituent of prominence, although hornblende more nearly represents the average composition.

Magnetite is present in large amount, over 10 per cent being present in some sections, and it, and chlorite developed in light-green flakes and strings throughout the slides, are most prominent.

Although it is apparently a basal mass the diorite has been through other processes than mere crystallization from the magma. The microscopic aspect of samples from certain localities seems to point to a granulation and recrystallization of the original rock, and in view of the neovolcanics which are so prominent over the area, some metamorphism is to be expected. There is enough evidence in the numerous slides examined to make it certain that, although basal in position, the diorite is not, strictly speaking, representative of a deep-seated igneous mass. It shows variation of structure and composition identical with those exhibited by an extrusive and although subsequent alteration may be, and probably is, responsible for many of these variations, it seems to be a more justifiable hypothesis that the diorite, although now it is stratigraphically the basal mass of Luzon, at the time of its origin was, in

part at least, extrusive and intrusive in relation to some still older formation of which, so far, no trace has been seen. Five analyses of samples of the diorite from various localities are as follows:

Analyses of the Benguet diorite.[4]

Constituent.	I.	II.	III.	IV.	V.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture at 110° (M—110°)	0.37	0.32	0.46	0.16	0.18
Loss on ignition (M+110°)	3.16	3.54	3.24	.75	3.24
Silica (SiO_2)	49.89	51.08	49.20	51.48	50.71
Alumina (Al_2O_3)	1.87	1.47	3.64	20.31	4.74
Ferric oxide (Fe_2O_3)	2.61	3.57	.84	6.24	2.26
Ferrous oxide (FeO)	23.47	25.30	25.00	3.46	20.64
Calcium oxide (CaO)	10.75	8.15	10.66	8.86	13.48
Magnesium oxide (MgO)	6.57	4.12	6.76	4.29	4.21
Potassium oxide (K_2O)	.09	.22	.06	2.07	.18
Sodium oxide (Na_2O)	2.01	2.13	.76	3.01	1.03
Total	100.79	99.90	100.62	100.63	100.27

Number I represents the porphyritic variety from the "Middle Reef."

Numbers II, III, are from the Antamok River.

Number IV is from Gold Creek.

These analyses should be compared with the following ones, made on samples from the Lepanto area on specimens of the "Mancayan diorite" which probably were fresher:

Analyses of the Mancayan diorite.[5]

Constituent.	I.	II.	III.	IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture (—110°)	0.50	0.28	0.38	0.12
Loss on ignition (+110°)	2.74	1.38	.70	2.26
SiO_2	50.67	51.00	47.98	47.94
Al_2O_3	21.21	18.01	18.94	21.96
Fe_2O_3	11.31	.23	7.08	2.48
FeO	.21	9.31	3.98	3.42
CaO	6.86	8.89	11.01	12.63
MgO	4.10	6.53	7.06	6.83
K_2O	.10	.46	.44	.19
Na_2O	1.41	4.42	2.56	1.49
Total	99.11	100.51	100.13	99.35

[4] Analyses Numbers I, II, III and V are by Dr. R. F. Bacon, and Number IV is by Paul J. Fox of the Chemical Laboratory, Bureau of Science.

[5] Analyses of Mancayan rock are by Mr. L. A. Salinger, Chemical Laboratory, Bureau of Science, Manila, P. I., 1905.

A comparison will show that although the silica remains fairly constant in amount, there is very little stability in the percentages of the other constituents excepting in the soda. This fact is not extraordinary and, indeed, it might be expected from variations in the magma in a distance of 50 miles, and from the subsequent alterations to which the rock has been subjected.

The exposure of the diorite in the Antamok River is continuous from Pakdal to a point a mile below Antamok, where a granitic intrusion (to be described later) comes in. The valley of Gold Creek is also in this rock, from its junction with the Batuaan to the headwaters at Pakdal.

On the north side of the area diorite again crops out where the drainage north and west of Baguio has cut deeper into the surface, and in various places in the Bued River cañon, where later sedimentaries and extrusives have been cut through, good exposures of the diorite are laid bare.

From below Camp IV, or Kias, on the Benguet road, the diorite does not outcrop, later extrusives and sedimentaries taking its place in the river bed, and it is evident from the occurrence of a massive intrusion of more granitic character to the east of this, that from this point on, the dioritic exposure leads off to the east toward the *Cordillera Central,* or in other words that on the topography of this basal mass, this southernmost point represents the limit of exposure of any great elevation. From here to the south, the diorite is evidently considerably lower and as may reasonably be supposed, is buried in the plains region between Benguet and Manila by a great thickness of recent sedimentaries.

INTRUSIVES.

About a mile to the south of Antamok, on the river of the same name occurs a massive exposure of a rock which here is classed as an intrusive, but which may possibly be but a phase of the diorite. On the Antamok and Batuaan Rivers, both of which cut across the contact between the diorite and the intrusive, the contacts are obscured by heavy talus and wash, and the relative ages of the formations, if they differ, can not be determined. The float on the Antamok River seems to show all variations in appearance from the one rock to the other. The rock may be classed in the field as a granite or quartz diorite. It is a hard, light-green massive rock showing to the eye quartz, feldspars, and a dark-green hornblende (?) arranged in a granular holocrystalline structure with particles of a light-green secondary mineral scattered throughout the feldspars. Under the microscope the minerals exhibited are quartz, plagioclase, amphibole and magnetite. The quartz does not form a conspicuous constituent and it occurs as an interstitial filling. The extinction angles measured on the plagioclase show it to be oligoclase in

idiomorphic crystals showing zonal growth and considerable polysynthetic twinning. The amphibole is normal hornblende and the magnetite seems to occur principally as inclusions in the former, or adjacent to it. In the Bued River cañon, where the same rock occurs, a marked peculiarity is developed, which appears to be the presence of inclusions of diorite caught up in the quartzose magma. This "Kugelstruktur" (Rosenbusch) when examined under the microscope, is seen to be due to difference in texture, in fineness of grain, rather than in any difference of mineralogical composition, and as before, the sections show plagioclase, hornblende, magnetite and quartz, with a slight development of accessory sphene and secondary iron oxide. No explanation of this, other than variation in the magma, can be offered. The area covered by this phase of the quartz diorite is considerable, to judge from the length of the exposure in the Bued River cañon, and over all the area examined, these "inclusions" prevail. Although mapped as a separate mass, the weight of evidence tends to the view that the diorite assumes a more quartzose variation only locally, and that the Batwaan Creek area is a part of the diorite core.

Many small dikes of basalt cut through this rock, but they are unimportant, excepting that the directions of the dikes seem to be quite uniformly along east and west lines. In common with the system of ore deposits in the diorite, the majority of the veins striking east and west, or approximately in that direction, this prevailing direction would point to a line, or rather a direction, of weakness in the main mass of the rock. Three analyses [6] of these rocks are as follows:

Analyses of the basalt.

Constituent.	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Moisture at 110° (M—110°)	0.14	0.08	0.13
Loss on ignition (M+110°)	1.61	1.08	0.77
Silica (SiO_2)	57.49	58.35	57.06
Alumina (Al_2O_3)	18.40	16.70	20.00
Ferric oxide (Fe_2O_3)	5.46	4.08	3.03
Ferrous oxide (FeO)	1.71	3.28	3.01
Calcium oxide (CaO)	7.61	7.71	7.18
Magnesium oxide (MgO)	3.05	3.29	3.27
Potassium oxide (K_2O)	1.99	2.87	3.06
Sodium oxide (Na_2O)	3.38	2.62	2.95
Total	100.84	100.06	100.46

Numbers I and II are from Antamok River, Number III, from Batuaan Creek exposures.

[6] Analyses by Paul J. Fox, Bureau of Science, Manila.

EXTRUSIVES.

The occurrence of comparatively recent eruptive rocks over a large part of the Baguio district is particularly noteworthy. North of the areas of quartz diorite, all the elevations are capped with extrusives of various types, but all show relations which point to one petrographic province for the series. Andesites and allied rocks prevail.

An exposure of limited extent within the area studied on the ridge east of the Antamok and east of the river is of a light gray-green volcanic rock which can not be classified in the field, more closely than as an augite-leucocphyre, although even this porphyritic development is rare and the rock generally is almost a felsite. Under the microscope, sections exhibit an orthophyric structure, the rock being composed of plagioclase (almost invariably fragmental) augite, and magnetite.

Determination of the feldspar is difficult, but measurements on one Carlsbad twin gave angles of extinction corresponding to oligoclase and while much shattered, the crystals are truly idiomorphic. Pyroxene is present in small amount throughout the slides, with sufficient indication of idiomorphism to justify the use of the term, and from the structure it is evident that crystallization of the augite has taken place later than that of the feldspars. The rock is much decomposed, breaking down into epidote and magnetite; chlorites are present in small amount, closely associated with the feldspars and augites. All sections show clearly that the rock is an extrusive (andesite), but that during crystallization or subsequently, great strain has developed, so that the rock is almost fragmental.

Two analyses[7] of this rock are given:

Analyses of the andesite.

Constituent.	I.	II.
	Per cent.	*Per cent.*
Moisture at 110° (M—110°)	0.44	0.52
Loss on ignition (M+110°)	2.23	2.04
Silica (SiO_2)	53.92	54.10
Alumina (Al_2O_3)	18.68	19.01
Ferric oxide (Fe_2O_3)	4.27	4.32
Ferrous oxide (FeO)	2.65	2.45
Calcium oxide (CaO)	8.85	8.90
Magnesium oxide (MgO)	2.93	3.02
Potassium oxide (K_2O)	2.66	2.98
Sodium oxide (Na_2O)	2.92	3.08
Total	99.55	100.42

[7] Made by Paul J. Fox, Chemical Laboratory, Bureau of Science, Manila, 1906.

Many outcrops of andesitic rocks are exposed on the Baguio-Kias Ridge, all more or less closely related in that they evidently represent one period of volcanic activity. These rocks vary from typical augite-andesites and andesite-porphyries to hornblende-porphyry, and certain other exposures can only strictly be classified as dacites. The rocks are so closely related that they are mapped as "andesitic rocks" to show their occurrence as subsequent and younger formations.

The rock in general is porphyritic in structure, the light-colored feldspar-phenocrysts showing prominently against the darker groundmass. Occasional exposures were seen which show a more granitic texture, but these are comparatively rare. Sections from one of the typical exposures on the Copper King Creek at the mill of the mine of the same name, show a rather abnormal cryptocrystalline groundmass with abundant phenocrysts of zonally constructed plagioclase, of hornblende and of magnetite. Investigation of extinction angles of the feldspar shows it to be labradorite, with occasional twinning according to the pericline law. Actinolite is the representative of the amphiboles, it rarely is unaltered, and then it shows pleochroism.

Saussuritization has taken place to a considerable extent and in many instances only outlines of the original feldspar are left. Magnetite is abundant in minute grains and is closely associated with the actinolite.

Specimens showing a pronounced porphyritic structure were collected from a dike in the Bued River a half mile above Kias, the plagioclase phenocrysts measuring as much as 0.5 inch in length, set in a dark groundmass. Under the microscope the feldspars show the characteristic alteration of the albite twins, and much calcite and epidote is seen. Oligoclase and andesine are identified in the fresher crystals. There is a second series of phenocrysts of a smaller size developed in the groundmass, and these, although badly corroded, are undoubtedly remnants of muscovite. Magnetite is present to a considerable extent, and both hematite and limonite scattered through the groundmass and the muscovite phenocrysts are in almost all sections.

A large exposure of a fine-grained andesite which is apparently a transitional rock, is found at a greater distance up the Bued River from this dyke variety of the andesitic eruptives. Its groundmass is light in color and the amphiboles make up the majority of the phenocrysts which are visible to the eye. This variety represents one extreme of the andesitic series of the district, and that next described, an augite-andesite from the Baguio Plateau, cropping out just south of the civic center of Baguio, the other. Megascopically it is a heavy, dark rock, breaking with a conchoidal fracture with a metallic ring. Small phenocrysts are seen in the groundmass, which can not be identified. It weathers on the surface to a brown clayey soil and decomposition has taken place

PLATE IX. BUED RIVER BEDS.

along a series of three directions of cleavage leaving hard and compact rounded boulders in the subsoil.

Under the microscope, augite is the most prominent constituent, with twinning parallel to the macropinacoids. The feldspars are plagioclase; oligoclase, andesine, labradorite and anorthite all occuring in at least two generations, if not more. The groundmass is typically andesitic in structure. Magnetite, in fine grains, is prominent in the groundmass.

All of the younger rocks described above are of andesitic varieties and in fact, with the exception of the two closely related rocks, the basal diorite and quartz diorite no other igenous rocks have been seen in this area, excepting andesite and related extrusives. There is a close petrographic and geologic resemblance between this district and the region around Mount Shasta (California), which has been described by Diller in Monograph 15 of the United States Geological Survey, and in general, between it and many of the petrographic provinces represented by the Pacific coast cones of Mount Hood, Mount Rainier and others. Spurr [8] has also recently called attention to this "Pacific Zone" of andesitic rocks.

SEDIMENTARIES.

Exposures of sedimentary rocks, although more prominent in the immediately adjacent areas, occur in the Baguio district, and from these a series can be constructed giving some fairly accurate idea of the geologic history of this region. At the base of this series, resting on the diorite rocks beneath, is a conglomerate of considerable thickness, made up of the dioritic materials derived from the basal mass. None of the exposures show a sufficiently large section to allow the taking of accurate measurements, but the conglomerate certainly must be considerably over 100 feet in thickness. The beds consist of heavy conglomerate at the bottom, with sandstones and clay above. No fossils have been found in these beds, but the one-foot lignite seam in the upper measures and the conformability of the beds with the Baguio limestone directly above them establishes the fact at least, that they are only a little earlier and older than the fossiliferous limestone. The material has little uniformity of size, and the bowlders vary from pebbles to rounded masses of many tons' weight. No outcrops of the conglomerate base are visible in the area, only the upper measures being laid bare in the upper end of the Bued River gorge. However, below, in the same cañon, for a distance of a few miles, the whole series is admirably exposed. The formation dips to the south on the southern end of the highlands and a few miles to the northwest of Baguio, to the west, the beds curve around the dioritic islet like a cape. The upper beds in the vicinity of Baguio are fairly

[8] Spurr, J. E.: Geology of the Tonopah Mining District, Nevada, *U. S. G. S.*, (1905), 47.

rich in fossil remains, but they are in a bad condition for examination, and the best that can be said is to confirm the statement of Abella,[9] that present-day marine forms occur.[10]

Resting on the conglomerate base is a heavy limestone bed, in places metamorphosed to marble (Bued River below "Colgan's Camp") by later andesitic extrusives. Almost everywhere it is rich in fossil remains. It is a yellow-white limestone, hard and compact, and excepting at the outcrops on the greatest elevation, fairly resistant to erosion. The limestone on the hills to the west of Baguio is in places heavily stained with iron oxide, giving it a deep rose color. At the bottom of the Bued River gorge, at the "zigzag" on the Benguet road, iron oxide in excessive amount has given the limestone a basaltic appearance, due to its black color and extreme hardness. When the rock is seen in thin sections, calcite, in large and small grains, with occasional evidence of recrystallization, is shown practically to form its entire mass.

The sections show specimens of:

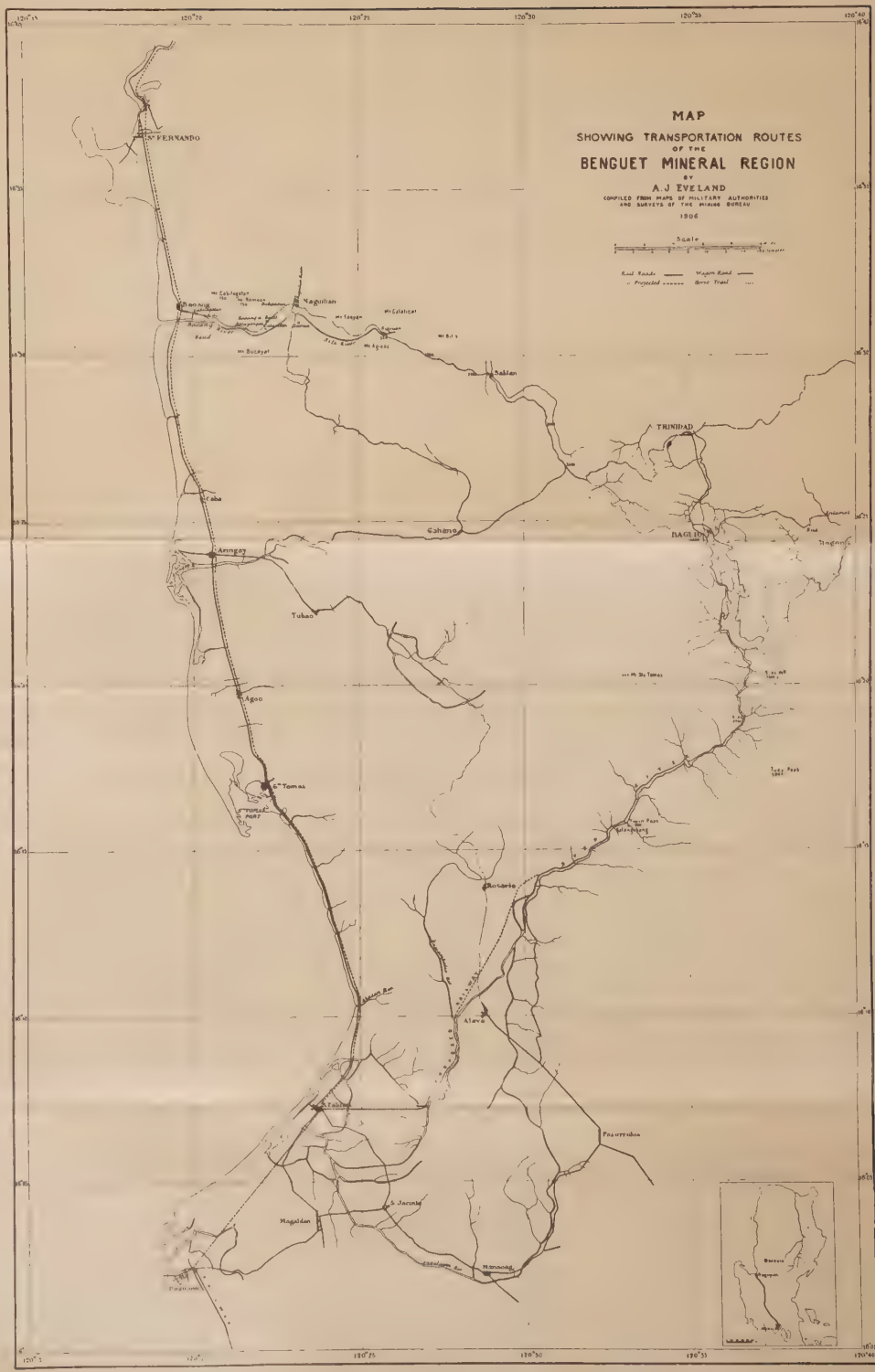
Operculina complanata Bast.
Lithothamnium ramossissimum Reuss.
Textularia megeriana (?).
Polystomella sp.
Orbitoides sp.

At least one fossil which may provisionally be pronounced a nummulite has been observed, the "alar prolongations" being well developed. Mr. W. D. Smith, who furnished the above data, has examined other limestones, in a region farther to the south in Luzon, in Cebu and in Batan Island, and all the paleontological evidence indicates the presence at one time of continuous beds of limestone, which can with fair safety be classed as Miocene, extending throughout the Philippine Islands, or at least throughout such parts of the Archipelago as were under the proper topographical conditions at the time it was deposited. A further study of broader areas than this small Baguio district is expected to add much to the stratigraphic correlation of these beds. An analysis[11] of the white limestone from the vicinity of Baguio is as follows:

[9] Abella: Terremotos de 1892 (1893), 33.

[10] Since this paper was written these fossils have been examined more carefully and with the aid of literature which we have since obtained we are able to single out several forms, the same as, or closely related to, Javan and Bornean forms which are certainly Tertiary and one, *Turbo borneënsis*, which seems to be confined to the Eocene. These fossils are all casts and poorly preserved, making exceedingly unsatisfactory material to work with.—W. D. Smith.

[11] Made by L. A. Salinger, Chemical Laboratory, Bureau of Science, 1906.


MAP
SHOWING TRANSPORTATION ROUTES
OF THE
BENGUET MINERAL REGION
BY
A. J. EVELAND
COMPILED FROM MAPS OF MILITARY AUTHORITIES
AND SURVEYS OF THE MINING BUREAU
1906
Scale
Road Roads
Wagon Road
Projected
Horse Trail
120°25
120°30
120°35
120°40
16°35
16°30
16°25
16°20
16°15
16°10
16°05
16°00
15°55
15°50
15°45
15°40
SAN FERNANDO
Naguilian
Sablan
TRINIDAD
BAGUIO
Gabano
Aringay
Tuba
Trinchera
Agoo
La Union
Rosario
Alava
Pugo
Magaldan
Bauang
Naguilian Road
Baguio
Trinidad
Benguet
Pangasinan
Agno R.

Map No. 1.

Analysis of the limestone.

Constituent.	Per cent.
Moisture (−110°)	0.16
Loss on ignition (+110°)	42.49
Silica (SiO_2)	1.90
Alumina (Al_2O_3)	1.72
Ferric oxide (Fe_2O_3)	.30
Ferrous oxide (FeO)	.04
Calcium oxide (CaO)	52.11
Magnesium oxide (MgO)	.97
Potasium oxide (K_2O)	.07
Sodium oxide (Na_2O)	.20
	99.96

TUFFS.

Exposures of what are undoubtedly pyroclastic rocks, now indurated to a solid rock mass, occur in the immediate vicinity of Baguio on the rounded hills near the town. The best exposures of these are on the Baguio-Trinidad road, near Baguio. The rock is a purple-brown hard and compact heterogeneous mass, to certain phases of which the name "eruptive conglomerate" has been given in the field. The name expresses the rock texture, which varies from a medium-grained variety to one which is extraordinarily coarse. The material is entirely andesitic, and two varieties of andesite are present, differing only in their groundmasses, as evidenced chiefly by the color of the latter. In thin sections, the loose texture of the rock is striking, being merely an aggregate of minerals, all of the grains being more or less rounded. The minerals present are the light-colored, monoclinic pyroxenes, hornblende, actinolite, plagioclase, magnetite and in areas, olivine, the tuff being in these localities more basaltic than andesitic. The pyroxene is the most prominent mineral, making up fully one-half the slides. It is greenish-yellow to almost colorless in various sections, and not pleochroic. It is fragmentary, very irregular, generally rounded and shows prismatic cleavage.

The feldspar is almost insignificant in amount, generally occurring in small grains. Magnetite is present in large amount, being second only to the pyroxene in abundance. The epidote which occasionally occurs is idiomorphic and can readily be distinguished from either hornblende or pyroxene by the marked basal parting. A microspherulitic structure of feldspar, quartz (?), and magnetite is noteworthy, as is also the intergrowth of feldspar and hornblende.

This rock in addition to the Baguio outcrops, is very prominently exposed on the road through the Pias Valley and on the Copper King road near Loacan. Other exposures on the east side of the Antamok

River show that the formation has existed, at one time, over a greater area from which it has been eroded. It is probable that field work beyond the district will also show this striking rock.

ORE DEPOSITS.

Although the present paper was planned as a contribution to economic geology, the study of the area has shown that the present stage of development of the ore deposits which have so far been found, does not warrant an extended investigation of them at present, nor would it, under such circumstances, be of more than descriptive value. It is therefore unnecessary more than briefly to touch on the occurrence of valuable ores within this district.

The native (Igorot) has for a long time, in a semi-skilled manner, worked such gold-bearing rock as has come to his attention, and the presence of the old working naturally led to their exploitation by the American miners, most of whom came in the army of occupation within the last decade. The Baguio district up to the present time has been prospected or developed in three, more or less distinct, districts, the Kias region, the Copper King or Bued River region, and the Antamok region. In all of these districts, deposits occur, associated with the igneous basal diorite or the closely connected volcanics.

SUMMARY OF THE GEOLOGY.

The geology of this region shows that we have a basal mass of dioritic rocks as the oldest rock which is laid bare, and this may be accepted as the beginning of the geological history of Luzon, until further data are collected from wider areas. During the gradual and prolonged submergence of this base, which is probably an eroded stump in the form of an islet, the basal conglomerate of the Bued River was laid down and on it the rest of the series of sandstone and clays, in which so far no fossils have been found. The limestone of the Bued River was built upon these in perfect conformity, and all paleontologic and stratigraphic evidence so far goes to show that this building occurred during the Miocene, after uplift and folding, erosion and base leveling commenced. Following this, or possibly at the beginning of the Miocene, that neovolcanic period began which also produced the "eruptive conglomerate" and tuffs at a later time. During this period the ore deposits which may have existed in the basal rocks may have been modified, and later deposits formed.

To judge from the physiographic evidence, there have been minor changes in level, in addition to normal base-leveling, which have produced the topographic features of the district.

RECONNAISSANCE MAP
OF
BENGUET MINERAL REGIONS
LUZON P. I.

BUREAU OF SCIENCE

DIVISION OF MINES

LEGEND

- Alluvial
- Andesitic Eruptives
- Tuff Beds
- Baguio Limestone — BUED RIVER SERIES
- Basal Conglomerate — BUED RIVER SERIES
- Quartz - diorite — BASAL
- Diorite — BASAL

PAKDAL
KISAD
BAGUIO
ATAB
LUBAS
LOACAN
PIAS
TUCHING
BUA
BACTO
MUYOT
GUMACHAN
BIRAC
ACUPAN
KIAS
Mt. SANTO TOMÁS OR TONGLON
San Fernando Trail
Bua Road
Bengtet Road
Mola River
Copper King Road
Copper King Creek
Bued River
Emerald Creek
Kias Trail
Balwaan Creek
Balalok Creek
Antamok River
Gold Creek or R. Silt
BENGUET CONSOLIDATED MINING Co.
BUA MINING Co.
ANTAMOK
J.E. Kelly
MILL

SCALE = 1:24.000

2000 1000 0 2000 4000 6000 8000 Ft

CONTOUR INTERVAL - 100 FT

TOPOGRAPHY BY A. J. EVELAND
BAGUIO RESERVATION BY C. H. GUERDRUM
BUED RIVER CAÑON BY MAJ. L. W. V. KENNON U.S.A.
GEOLOGY BY A. J. EVELAND
1906

ILLUSTRATIONS.

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PETROGRAPHY OF SOME ROCKS FROM BENGUET PROVINCE, LUZON, P. I.[1]

By Warren D. Smith.
(*From the Division of Mines, Bureau of Science.*)

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Benguet rocks.
Diorite.
Quartz diorite.
Dacite.
Andesite.
Andesite tuff.
Andesite porphyry.
Graywacke.
Foraminiferal limestone.
Illustrations.

INTRODUCTION.

Mr. Eveland in his paper "Notes on the Geology of the Baguio Mineral District"[2] has described the field relations of the rocks, the more detailed petrography of which I have taken for the subject of this paper.

In the following pages I propose to give a description of each rock, which I wish could have been much more minute and exhaustive but time did not permit of more extensive work. I have included diagrams and photomicrographs and in addition have added some tables, using the quantitative classification.[3] Many of our Philippine rocks are classified with difficulty according to this system, owing to their greatly decomposed and altered condition, and it is only applicable to comparatively fresh rocks, which we rarely obtain except in mines and road cuttings, and of these unfortunately we as yet have few.

[1] Supplementary to the paper by A. J. Eveland on the "Geology and Geography of the Baguio Mineral District." *This Journal*, Sec. "A," Gen. Sci. (1907), 4, 207.

[2] Eveland, A. J.: Notes on the Geography and Geology of the Baguio Mineral District. *This Journal*, Sec. "A," Gen. Sci. (1907), 4, 207.

[3] Quantitative Classification of Igneous Rocks; Chicago (1903).

More than one geologist [4] who has made studies along the great Pacific arc has remarked upon the striking similarity existing in the geology along all its points in California, Alaska, Japan and the Philippines.

A member of the United States Geological Survey, one who has had abundant opportunity to study the geology both of western America and portions of Asia, writes to me as follows:

> Although the Pacific lies between and seems to separate you from the more familiar phases of the geology of North America, I am of the opinion that geologically you are more in touch with our western coast than the man who is studying the geology of the eastern United States. The ocean basins are the sources of the great dynamic effects which characterize the continental margins, and there is more likeness between the opposing shores of the Pacific than there is between the opposite sides of the continents. I have been interested in the course of my work to find that the geology of California is the geology of central China, and that there is a close likeness even in the character and date of mineral deposits between our Western Cordillera and the East Indies. These similarities in geologic history, in orogeny, in vulcanism, and even in mineralization are too close and too long continued to be fortuitous. We shall reach an understanding best by regarding the ocean as the center and the continental region as the periphery, and by recognizing that the major phenomena differ when we cross the periphery from the sphere of activity of one ocean to that of another.

I must say, after attempting to make use of the quantitative classification, that it is not well adapted to our Philippine rocks. I believe that in their almost universal condition of decomposition here, classifying them after this manner would only be misleading. It does not seem justifiable, at least in many cases, to employ a system which neglects the actual mineral composition and uses an altogether arbitrary standard or norm.

The papers by Mr. Eveland and myself, then, only serve as an introduction to this region. There are many questions which we have thought over and upon which we have gathered some notes, but the time is not ripe for the close study which they demand for their solution. Some of these are:

1. Relation of the period of vulcanism to the deposition of the ores.
2. Relation of the vulcanism to the physiography.
3. Relation of amount of ejecta to elevation and subsidence.
4. The probability of past glaciation in the highlands of north central Luzon.

In this connection I may state that there are many features, such as boulders and boulder-clay, strongly resembling moraines; ponded drainage; peculiarly rounded and veneered hills; valley trains, etc., which have not received full treatment in the foregoing paper of this number for several reasons, the chief among these being the incompleteness of the evidence. Markings suggestive of glacial striæ have been

[4] Becker, G. F.: Geology of the Philippine Islands—Extract. *21st. An. Rept. U. S. G. S.* (1902), 518.

reported to me by men who are in their own fields considered good observers. It is needless to say that before such a startling announcement as glaciation in this region can be made much more work in the area should be carried on, and this is proposed for the early part of 1908. The bearing of the possible discovery of glaciation upon problems of tropical animal and plant distribution, would of course be profound.

I have made use of the new method of Dr. Eugene Wright in the determination of feldspars and have found it highly satisfactory. It will be recalled that this method makes use of a series of standardized oils composed of definite proportions of cedar, cinnamon and clove oil.

I wish here to acknowledge some assistance rendered by my colleague, Mr. H. G. Ferguson, in the preparation of the tables in this paper.

Bibliography of Benguet petrography.

1878—*Drasche, R. Von.* Fragmente zu einer Geologie der Insel Luzón (Philippinen), mit einem Anhange über die Foraminifera der Tertiären Thone von Luzón, von Felix Karrer. Vienna, Gerold's Sohn.

1881—*Oebbeke, K.* Beiträge zur Petrographie der Philippinen und der Palau-Inseln in *Neues Jahrbuch f. Mineralogie*, etc. Beilage, Band I, Stuttgart, Koch.

1893—Abella y Casariego, Enrique. Terremotos experimentados en la isla de Luzón durante los meses de etc. Manila Chofré 8°, 110 pp. 1 diagram and map.

1893—Abella and others. Estudio descriptivo de algunos manantiales minerales de Filipinas etc. Manila, Chofré, 8°, pp. 150.

List of Benguet rocks described in this paper.

Series No.	Field No.	Name.	Locality.	Page.
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BENGUET NO. 4.—QUARTZ DIORITE.

The primary minerals present are plagioclase, amphibole, quartz, magnetite.

Feldspars.—The plagioclases correspond to oligoclase, as all the extinction angles are almost without an exception low, 8° or very close to that figure; the index of refraction is also lower than that of quartz, showing that these feldspars could not be either labradorite or anorthite. They occur in idiomorphic crystals showing zonal growth in many cases and much polysynthetic twinning according to the albite law. No good Carlsbad twins could be made out, but this form of twinning does occur. The average diameter of the feldspar sections varies from 0.5 to 1.5, and 2 millimeters is the extreme observed.

Quartz.—Occurs as an interstitial filling. It does not form a conspicuous constituent of any of the sections from this rock.

Amphibole.—Some ragged sections parallel to prism and fragments of basal sections form a small portion of the section. The amphibole is grass green, extinction angle about 17°.

BENGUET NO. 12.—QUARTZ DIORITE.

This is a section of a typical quartz diorite. It is quite fresh, showing little or no alteration. The texture is granitic, the holocrystalline, fabric *hypidiomorphic-granular.* The minerals of the rock are plagioclase and orthoclase feldspar, hornblende (actinolite) quartz, magnetite, and accessory apatite. The feldspars for the most part are plagiocalse, exhibiting both Carlsbad and albite twinning. From the extinction angles which were taken on a section cut normal to the albite twinning I made out this piece at least to belong somewhere near the middle of the series, oligoclase or labradorite. Some orthoclase is present, associated more or less with the quartz. It is decidedly not the dominant feldspar. The amphibole is the pleochroic, grass-green variety known as actinolite with pleochroism as follows: *b*=colorless to yellow; *c*=dark green. Quartz occurs wholly as interstitial material. Magnetite is found as minute, rounded grains inclosed by hornblende.

A series of measurements on this slide establish the following approximate proportions of the various minerals, from which was calculated the following analysis.

Constituent.	Per cent.
Quartz	2.94
Plagioclase	67.09
Hornblende	22.93
Magnetite	6.28
Olivine	.73

Magnetite is largely confined to the region of the amphiboles, either as inclusions or in juxtaposition.

Accessory minerals an almost entirely lacking or so inconspicuous as to warrant no lengthy search for them.

The rock is a *quartz diorite.*

Constituent.	Calculated from mineral contents.	Calculated by chemical analysis.
	Per cent.	Per cent.
SiO_2	56.89	57.06
FeO	8.58	6.04
Fe_2O_3		
Al_2O_3	17.52	20.00
MgO	2.9	3.27
Na_2O	7.32	2.95
CaO	3.97	7.18
H_2O	.....	3.06
	97.18	100.00

Plate II, fig. 1, is a photomicrograph, taken with polarized light, of this rock.

Remarks. A greater number of measurements would doubtless raise the silica content by showing more quartz. In this calculation the orthoclase was taken with the plagioclase. This, in close work, strictly should not be done. Making allowance for orthoclase we should have a lower Na_2O figure and about 3 per cent of K_2O.

Examination of additional sections of this rock revealed some small amount of biotite.

TABLE I.—*Benguet No. 12.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Anorth.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	57.06	951	198	288	230		24	91	116
Al_2O_3	20.00	196	33	48	115				
Fe_2O_3	6.04	19				19			
FeO		42				19	3	29	
MgO	3.27	82					11	71	
CaO	7.18	129			115		14		
Na_2O	2.95	48		48					
K_2O	3.06	33	33						
	99.56								

Constituent.		Norm.				
Quartz		0.116	6.96	Q 6.96	Salic 82.43	
Orthoclase		.033	18.35			
Albite		.048	25.15	F 75.47		
Anorthite		.115	31.97			
Diop	Ca	.014	1.63	3.13	P 12.87	Ferric 17.28
	Mg	.011	1.10			
	Fe	.003	.40			
Hyp	Mg	.071	7.10	9.74		
	Fe	.020	2.64			
Magnetite		.019	4.41	M 4.41		
			99.71			

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 3. Andase.
Subrang 3. Shoshonose.

BENGUET NO. 13.—DIORITE.

This slide is from a *diorite* also, but one which is not so fresh. It contains triclinic feldspars, most probably labradorite, as the following figures were obtained from Carlsbad twins, 20° to 26° and 11° to 12°. One very noticeable feature of this slide is the great number of small, rounded grains of quartz and feldspar in the interstices of the plagioclases. The slides give the appearance of the rock having suffered a granulation and recrystallization in some portions. This hypothesis is apparently supported by the appearance of some of the feldspars. One in particular is something like Plate I, fig. 2. The characteristic alteration in zones in the plagioclase is shown in Plate I, fig. 2. In one of the Carlsbad twins a structure very similar to what is known as microperthitic is to be seen.

The amphibole is of the green, pleochoroic variety, actinolite, but much altered.

The above figures on the Carlsbad twins are supported by investigation of other slides from the same rock where sections normal to the albite twinning gave 31° to 33° maximum extinction, proving pretty conclusively that the feldspar is *labradorite*. The structure of this rock may be termed hypidiomorphic granular to cataclastic.

BENGUET NO. 16.—DIORITE.

This slide is largely made up of plagioclase feldspars which show much polysynthetic twinning. No twinning other than the Albite was noted. The other minerals are magnetite, chlorite and calcite, these latter being very intimately associated, as they are all undoubtedly products of the alteration of the feldspars.

As far as the feldspars are concerned, the structure is described by Rosenbusch's term pan-idiomorphic, and pan-idiomorphic-granular with reference to the whole rock. The feldspars were apparently the first to crystallize from the magma. In some sections the structure is almost that of a porphyry.

No good sections suitable for measuring extinction angles of the plagioclase were found, although from the presence of the calcite one would infer that they belonged to the lime end of the series. Some of these feldspars show a structure closely resembling what is termed microperthitic, and which is usually produced by an intergrowth of two or more kinds of feldspar.

The chlorite is the light green mineral with low index of refraction, it is scattered in flakes and stringers all through the slide. However, it has not been seen anywhere in the slide to possess a radial structure, usually so prominent in the case of this mineral.

In several patches in the slide the three minerals, magnetite, chlorite and calcite are grouped indiscriminately together as if resulting from the alteration of some former ferromagnesian mineral, rich in calcium,

such as diopside or actinolite. One or two very large patches of calcite make it appear quite probable that some calcium has been introduced from the outside.

Magnetite constitutes fully 10 per cent of some of the slides of this rock. There is also a small amount of pyrites.

TABLE II.—*Benguet No. 16.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Acmite.	Mag.	Diop.	Hyp.	Oliv.
SiO_2	49.89	832	6	108	56		384	260	18
Al_2O_3	1.87	019	1	18					
Fe_2O_3	2.61	016			14	2			
FeO	23.47	326				2	128	193	27
MgO	6.57	164					64	87	13
CaO	10.75	192					192		
Na_2O	2.01	032		18	14				
K_2O	.09	001	1						
H_2O	3.53								

Constituent.		Norm.				
Orthoclase		.001	0.56	F 9.99	Sal 9.99	
Albite		.018	9.43			
Acmite		.014	6.47	6.47		
Diopside	Ca	.192	22.27	45.57	P 83.58	
	Mg	.067	6.40			
	Fe	.128	16.90			
Hyp	Mg	.087	8.70	31.54		Fem 88.44
	Fe	.173	22.84			
Oliv	Mg	.006	.84	4.40	4.40	
	Fe	.021	3.56			
Magnetite		.002	.46		M .46	

Class V. Perfemane.
Subclass I. Perfemone.
Order 1. Maorare.
Section I. Caroliniare.
Rang 1. Websterase.
Subrang 4. (Doferrous.)

BENGUET NO. 150.—GRAYWACKE.

Macroscopic.—Is an aphanitic, medium-grained, hyp-automorphic granular rock of a speckled white and green color. This rock is not very unlike a coarse-grained sandstone. Feldspar is practically the only mineral distinguishable with the naked eye.

Microscopic.—This is unmistakably a fragmental rock, but it is not so easy to say positively whether it is a normal sedimentary derived from land wear or of pyroclastic origin. Under the microscope one sees a confused mass of minerals, some rounded and some angular, consisting of quartz, orthoclase, plagioclase, magnetite, chlorite, and numerous saussuritization products such as quartz, epidote and possibly calcite. Under

a high power the closely knit appearance of the mass almost leads to the belief that this is a true igneous rock, but with lower power, when a proper view of the whole can be obtained, its true texture is plain and it is evident that the pseudo-igneous texture is due to the matrix of chlorite and iron compounds which cement the larger grains.

Remarks.—I would call this rock a graywacke for the following reasons:

1. Its composition.

2. Its fabric, the rock consisting of an aggregate of more or less independent, rounded and angular minerals, not rock fragments as in the true tuffs (see numbers 101 and 103).

BENGUET NO. 153.—QUARTZ DIORITE.

Macroscopic.—This is a phanero-crystalline, medium-grained (with finer grained inclusions) xenomorphic rock of a pepper and salt color. The rock consists largely of more or less irregular and ill-defined feldspar and ferromagnesian minerals, the darker minerals possessing more nearly idiomorphism. In the white, dull feldspar patches there are minute pinkish areas of orthoclase. The predominent feature about this rock is the magmatic differentiation. The cryptocrystalline areas, usually 1 to 2 cubic centimeters across, are in every case darker than the remainder of the rock and the border between the two areas is generally sharp.

Microscopic.—In the hand specimen this is not greatly unlike the Kobe (Japan) granite. For the most part it is coarse grained and possesses the typical granitic texture. In both rocks the characteristic feature is the areas of darker, more fine-grained portions, which almost have the appearance of foreign material caught up in the crystallizing magma. This is the "Kugel Structur" of Rosenbusch and described by him from the Corsican "Kugeldioriten von S. Lucia di Tallano bei Sartene." (See p. 120, Rosenbusch, Massige Gesteine.)

Two very distinct areas are seen under the microscope, which, however, differ more in texture and abundance of certain minerals than in the mineral composition itself. The same minerals appear in both areas, but in different proportions. The minerals found are:

Primary. { Plagioclase. Hornblende. } Accessory: Sphene.
{ Magnetite. Quartz. } Secondary: Iron oxide.

This makes the rock a *quartz diorite*. The quartz is not secondary, as is shown by its relations to the other minerals, at least it is not the case with all of it.

Plagioclase.—This is the most abundant constituent of the slide, found in large, idiomorphic sections, showing both albite and Carlsbad twinning. Extinction angles on section showing albite twinning gave the figures 20° to 22° which would throw these plagioclases in with andesine.

Hornblende.—For the most part in broken prism sections, pleochroic c = dark green, a = yellowish, in thinner section it would be nearly colorless, it forms the next most abundant constituent of the slide, most prominent in the "Kugel" areas, where it is as abundant or even more so, than the feldspars. However, it occurs in these areas in very small, irregular grains, much smaller than in the more coarse-grained portions. Where good contacts can be studied it appears that the hornblende crystalized first.

Quartz.—Probably makes up 2 to 3 per cent of the slide as interstitial material.

Magnetite.—Present, but not very abundant. Largely confined to the body of the hornblende.

Sphene.—Occasional, stray crystals of small size.

Iron oxide stains the slide here and there.

Plate II, fig. 2, is a photomicrograph, with polarized light, of this rock.

Remarks.—From all the indications that can be gleaned from the slide, the darker "Kugel" areas simply represent a differentiation in the original magma. This part, it is my idea, was a little richer in the constituents that make up the ferromagnesium minerals; certain conditions must have prevailed more favorable for the production of hornblende than pyroxene, these were conditions of pressure, temperature and the composition of the magma, the intimate relations of which are just beginning to be understood. The results seem to be more in the nature of a concretion and the law of mass action appears to have entered largely into the process.

An examination of the boundary between the darker, fine-grained areas and the rest of the rock does not reveal a sharp line, although on macroscopic examination it does appear so. Under high power the boundary is irregular and chrystals from both areas penetrate each portion. Quartz seems to be more abundant along the contact than anywhere else in the slide. Just at that point the rock solution may have been depleted of alumina, etc., through the formation of excessive amounts of hornblende in the "concretionary" part.

BENGUET NO. 116.—DACITE.

Macroscopic.—A hypocrystalline, rather aphanitic rock, which has a somewhat porphyritic fabric and is greenish-yellow. The rock has a dense, bluish, fine-grained ground mass in which are numerous phenocrysts of epidote, themselves not large, rounded areas which appear to be decomposed feldspars and occasional, clear, limpid, more or less rounded or irregular, areas of quartz. There are very few ferromagnesian minerals visible in the hand specimen, and they are mere black specks.

Microscopic.—The prominent features of the slide are:

1. The saussuritized feldspar (plagioclase) phenocrysts.
2. The comparatively clear, rounded phenocrysts of quartz.
3. The ground mass in places quite trachytic, in others glassy, the whole having a felty or hyalopilitic character.

The existence of the ferromagnesian minerals, pyroxenes, or amphiboles can only be inferred as alteration has left no recognizable remnants.

Remarks.—The alteration of the plagioclase has gone so far that scarcely a trace of the polysynthetic twinning can be made out; however, the outline of the original mineral is still preserved. The interior of these phenocrysts is usually taken up with quartz and epidote, some of which is the low, doubly-refracting zoisite.

Pyrite is abundant in some of the slides, magnetite in all of them.

BENGUET NO. 106.—HYPERSTHENE AUGITE ANDESITE.

Macroscopic.—An almost black aphanitic, for the most part microcryptocrystalline rock, but plainly porphyritic. The larger phenocrysts, not over 2 millimeters in diameter, are jet-black amphiboles or pyroxenes, while there are smaller, lath-shaped feldspars, which are apt to be overlooked unless the light strikes them. These are about 2.5 millimeters in length by 0.5 millimeter wide, and are striated. Occasional larger, glassy spots of what is probably quartz are also to be seen.

Microscopic.—This rock in thin section reveals a distinctly porphyritic structure, large, square and brick-shaped feldspars, plagioclases, and pyroxenes occur, also idiomorphic in a groundmass, which varies from vitreous to cryptocrystalline, and also holocrystalline.

There are a number of large, irregular, also sometimes square sections of magnetite in the slide, as well as innumerable fine grains of it in the groundmass.

The plagioclases show both albite twinning and zonal structure. Sections normal to the albite laminæ give extinction angles of 26° to 28°, thus corresponding to andesine. One zonally built crystal of feldspar appeared to have an outer coating of anorthite. Carlsbad twins also are not infrequent but the thickness of most of the slides of this rock prevent close investigation of their extinction angles. Plate I, fig. 3, shows typical appearance of altered feldspar or rather of one which is about three-fourths decomposed.

The pyroxene is largely hypersthene and exhibits marked pleochroism, but augite, which reveals none, is also to be seen in the slide. Plate I, fig. 4, shows the habit of the hypersthene in this rock.

Plate III, fig. 1, is a photomicrograph of this rock.

Remarks.—In one place augite has grown around the hypersthene, having crystallized later. It would also appear that the plagioclase had crystallized after the hyphersthene. From evidence in the slide it would seem as if the felspar and the augite cystallized out almost simultaneously. Plate I, fig. 5, shows a basal section of augite twinned parallel to the macropinacoid.

It appears, from the descrptions by Diller, Iddings and Becker, that we have here a hypersthene-augite andesite very nearly identical with the recent lavas of Shasta County, California, and the Comstock Lode, Nevada. See *Bull.* **150** *U. S. G. S.*, Diller; also Geology of the Comstock Lode, Becker; also *Mon.* **20**, *U. S. G. S.*, 364.)

BENGUET NO. 107.—AUGITE ANDESITE.

Microscopic.—This rock is almost an exact duplicate of No. 155.

Phenocrysts of plagioclase and augite lie imbedded in a typical groundmass of small, lath-shaped feldspars arranged in an orthophyric manner, making a typical andesitic groundmass. Some of the slides are thick, so that this structure of the groundmass can not be seen, but one slide shows it well.

The feldspars show extinction angles varying from 10° to 31°, so that the phenocrysts vary from oligoclase to labradorite. All the phenocrysts are quite fresh. The augite occurs in idiomorphic sections, both basal and prismatic. One prismatic section (Plate I, fig. 6) shows twinning and cleavage. The twinning plane is not exactly parallel to *c*.

Magnetite is very abundant, but in rather small grains in the groundmass. In one slide there are remnants of a substance indicating the former presence of hornblende, but we can not be sure that the slide contains any hornblende or amphibole.

BENGUET NO. 101.—ANDESITIC TUFF.

Macroscopic.—This is a heterogeneous mixture of particolored fragments, which are angular pieces of lava in various states of crystallization. The groundmass is uniformly fine grained and dark-red to brownish-black in color. The fragments which we find well cemented here were evidently blown out of some volcanic vent and afterward rendered compact under water. Occasional large crystals of hornblende, 5 by 7 millimeters, can be seen. The rock fragments are for the most part hornblende andesite. The largest fragment in the hand specimen is 22 by 12 millimeters.

Microscopic.—These are sections from what we may term an "eruptive conglomerate," or more properly speaking, an agglomerate of eruptives. All the material appears to be andesitic, there being two main kinds. These two differ chiefly in the material of the groundmass and this is evidenced mainly by the color, one portion, making up the larger part of the slides, being dark reddish or brownish.

Green hornblende, actinolite, and the light-colored monoclinic pyroxenes are present making up about one-half the slide.

The feldspars are plagioclase, but more than this we can not tell from the slide, as alteration and thickness obscure the albite twinning.

Epidote as an original constituent is seen in one slide. It is perfectly idiomorphic and appears in outline as shown in Plate I, fig. 7.

The marked basal parting distinguishes this from hornblende or pyroxene. There is scarcely any pleochroism.

Plate III, fig. 2, is a photomicrograph of this rock.

Remarks.—One of the noteworthy features of this rock is the intergrowth of feldspar and hornblende. (Plate I, fig. 9.) The feldspar is found in irregular grains all through the hornblende with a sharp, clean-cut line between the two minerals. Their appearance is decidedly *not* that of alteration of the hornblende, for they are in a very fresh state.

Magnetite, as usual, is quite abundant, though in small grains.

BENGUET NO. 102.—ANDESITE TUFF.

Macroscopic.—This apparently is a phase, though somewhat different, of Nos. 101 and 103. The rock fragments are larger and somewhat more rounded. The different portions of the rock vary considerably in color—that is, they are almost black, the color changing through chocolate to greenish-yellow—and the grain varies from exceedingly fine-grained portions to those containing phenocrysts of considerable size.

Microscopic.—This rock is evidently an intermediate phase between Nos. 101 and 103. The mineral composition is practically the same, plagioclase, pyroxene, hornblende(?), and magnetite. If there is any quartz present, it is in very minute quantities. However, there are two very noticeable features as exhibited in one slide. One of these, and perhaps the most important, is the pseudo-microspherulitic structure. Plate I, fig. 8, will show the relationships.

The second feature is the fairly abrupt contact between the darker and lighter portions of the rock. The darker differs merely in the possession of more iron staining its groundmass. Under the microscope this line appears far less regular than in the hand specimen, and the two portions of the rock dovetail along this boundary.

BENGUET NO. 132.—ANDESITE PORPHYRY.

Macroscopic.—A coarse-grained, porphyritic rock consisting of large, approximately square phenocrysts of white, dull to greasy looking feldspars set in a cryptocrystalline groundmass of a bluish black color. An average phenocryst measures 7 by 9 millimeters. Minute grains of a white mica are found as inclusions of the feldspar. The groundmass is slightly vesicular.

Microscopic.—On microscopic examination the groundmass, and the phenocrysts as well, are seen to be cryptocrystalline. Alteration has gone quite far and this is the reason for the oily appearance of the phenocrysts which are of two kinds and sizes; the larger were originally plagioclase. This is proved by occasional albite twinning in the unaltered remnants. They are nearly quadratic in outline.

The smaller phenocrysts occur with lath-shaped outlines, sometimes in rude, pseudo-hexagonal sections but more often they are rounded and badly corroded, being accompanied by a dark-greenish reaction rim, probably consisting in part of ferrous iron. They are undoubtedly remnants of muscovite.

Some small amounts of magnetite, more hematite and limonite can be seen scattered throughout the groundmass and the muscovite phenocrysts. The alteration products of the muscovite could not be made out even with the highest power (oc. No. 3, obj. No. 9); all that could be seen was a granular mass or very small, irregular, doubly refracting bodies.

Plate IV, fig. 1, is a photomicrograph of this rock.

Remarks.—The alteration of the feldspars is the characteristic saussuritization, with calcite and epidote certainly formed.

By testing a fragment of the less altered portion of the feldspar with a standardized oil, I found the unaltered portions to have an index Na 1.545 to Na 1.554, corresponding to that of oligoclase and andesine.

BENGUET NO. 126.—ANDESITE PORPHYRY.

Macroscopic.—This rock in the hand specimen has a yellowish-gray color, rather fine texture, yet apparently it is granitic. Occasionally a patch of finer grained and darker material is present, suggesting an orbicular structure.

Microscopic.—In thin section the most striking feature of the rock is the state of alteration of practically all the minerals. The feldspars are no longer clearly recognizable. They are very much altered, but retain their original outlines. Their arrangement in places is almost ophitic, in others trachytic. Rounded and irregular grains of what was originally hornblende and magnetite are all that remain of the original minerals.

Chlorite in large patches with radial structure is the most prominent secondary mineral.

Calcite in veinlets and also as an alteration product of the feldspars is quite plentiful. Large patches of radial chlorite with blebs of calcite scattered through them are quite characteristic of the slide.

Some secondary epidote is found closely associated with the feldspars.

Remarks.—At first glance one might be inclined to call this rock detrital, but an occasional feldspar with idiomorphic outlines and the structure of the rock would preclude this.

From examination of the hand specimen and the slides I should call the rock a dike rock—a phase of andesite porphyry.

BENGUET NO. 23.—FELDSPAR PORPHYRY.

This is a porphyritic rock in which zonally built plagioclase feldspars are the phenocrysts. There are also some large magnetite crystal sections, more or less idiomorphic, in the slide.

The groundmass is trachytic and made up of small, lath-shaped sections, and an abundance of minute magnetite particles.

Calcite is fairly abundant, being associated with feldspars; in some cases large patches of calcite can be seen inclosing a few small grains of feldspar; then again the calcite occurs as irregular stringers through

the feldspar. Clearly it is a decomposition product of the feldspar. Chlorite is also in evidence in irregular patches between the larger minerals. It is almost impossible to specify the particular composition of the plagioclases, as no good prism faces nor sections cut normal to the albite twins were found. However, one zonally built plagioclase was investigated with the result that the center was found to have about the composition of oligoclase, with albite forming the outer shell. The only name I feel warranted in assigning to this rock is that of *feldspar porphyry*. The rock is far from being fresh. Plate IV, fig. 2, is a photomicrograph, with ordinary light, of this rock.

BENGUET NO. 103.—BASALTIC TUFF.

Macroscopic.—This rock is apparently made up of the same materials as No. 101, although it is in a much finer state. The groundmass is possibly somewhat more prominent and hence the rock is more nearly of its color, which is a chocolate-red. The largest fragments in this specimen do not exceed 3 millimeters in length. These is no effervescence with acids.

Microscopic.—When we study the slides of this rock the supposition that this is simply a finer state of No. 101 seems to be borne out, for few rock aggregates are seen as in No. 101, merely a loose textured aggregate of minerals, quite fragmental in appearance is visible. The grains are all more or less rounded, although not all to the same degree as in sandstone or quartzite.

The most abundant mineral of the rock is pyroxene, greenish-yellow in some sections, almost colorless in others, yet it is not pleochroic. It occurs as mere fragments, irregular and rounded, usually showing prismatic cleavage. Olivine also in rounded grains, colorless and possessing irregular cleavage cracks, can be seen in several places in the slide.

Magnetite is probably the most abundant mineral after pyroxene. It is sometimes seen inclosed in the pyroxenes. Feldspar is reduced to a minimum in these slides, usually occurring as very small grains and in one case only showing any distinct twin striations. In some of the slides fragments of actinolite were seen. These were generally pleochroic. The presence of both actinolite and augite is assured, as one portion of a basal section was found. These minerals are frequently seen to be surrounded by opaque masses of hematite and limonite.

Remarks.—The rock is clearly pyroclastic and owing to the presence of olivine would more properly be called a *basaltic tuff* rather than an *andesitic tuff*, as in the case of No. 101.

The large amount of quartz would presuppose an acid magma, far more acid than any which has ever been encountered in igneous rocks of this region. If this be considered a graywacke the quartz could naturally be segregated on the beach so as to give its present richness in silica. The slides show considerable

variation in the size of the grains, but this has no special significance, save the fact that the material was derived close at hand.[4]

Plate V, fig. 2, is a photomicrograph of a similar rock but not from this precise spot.

BENGUET NO. 108.—FORAMINIFERAL LIMESTONE.

Macroscopic.—This is an aphanitic, pink-colored rock with conchoidal to hackly fracture, it contains a few veinlets filled with rusty calcite. The rock on its weathered surface has a dirty, bluish-gray appearance. It effervesces strongly with acids.

Microscopic.—Under the microscope the rock is seen to consist chiefly of large and small grains of calcite with almost every conceivable shape, stained copiously with iron oxide, which of course gives it its red color. The rock also contains the remains of the two well known Miocene fossils, *Operculina complanata* Bast. and *Lithothamnium ramossissimum* Ruess.

Plate V, fig. 1, is a photomicrograph of this rock.

Remarks.—I have found these same forms in limestones from Cebú Island, Polillo Island, Lepanto Province, Luzon, and other localities.

LIMESTONE FROM THE BENGUET ROAD.

Macroscopic.—In the hand specimen this rock is quite black, in portions very fine-grained, in others crystalline; it is occasionally streaked with minute calcite veins. It is very fossiliferous, but as the rock is very hard it is difficult to remove the fossils, which are for the most part large bivalves.

Microscopic.—The dark color is due to an excessive amount of iron oxide in the matrix. Large amounts of calcite in more or less rounded grains are to be seen in the slide, these practically make up the entire rock. Fragments of foraminifera are quite abundant, but, owing to their state of preservation we can make little more than a guess as to their identity. Some of these very much resemble sections of *Operculina* and there is another section which suggests a nummulite as it possesses "alar prolongations" between the successive whorls.

Remarks.—This limestone in its lithology, fossils, and position is quite different from the upper limestone on the Baguio Ridge. It would seem very probably to be Eocene.

BENGUET NO. 124.—FELDSPAR PORPHYRY.

Macroscopic.—A hypocrystalline, fine-grained, bluish-gray rock which has xenomorphic shape and hypautomorphic arrangement of its crystals. The rock is rather prominently speckled with small amphiboles or pyroxenes, difficult to separate in a megascopic examination.

Microscopic.—Another badly decomposed rock, consisting of phenocrysts of saussuritized plagioclase in a groundmass of small, lath-shaped feldspars, for the greater part plagioclases, and quite fresh magnetite

[4] Wavy extinction is to be seen in some of the quartz and feldspars. This means strain due to pressure. Also there is evidence of secondary enlargements of some of the minerals, another sign of metamorphic action.

grains, chlorite, calcite, etc. Besides the phenocrysts of feldspar, there are fragments of hornblende crystals, but in most cases there is little left of these, they having altered to both chlorite and serpentine.

Plate I, fig. 10, shows one section of the hornblende in this slide. The extinction is parallel and normal to the cleavage. However, this is a monoclinic amphibole and not an orthorhombic one. The pseudo-orthorhombic appearance is due to the section being cut from some plane normal to the plane of the optic axes from (100) or (001).

A very peculiar feature of these slides is the figure represented by the diagram Plate I, fig. 11.

Remarks.—What this form may have been originally is certainly open to conjecture.

APPENDIX.

Below are three analyses of rocks coming from this province, but unfortunately the hand specimens have been misplaced so that no descriptions can be made.

TABLE III.—*Benguet No. 17.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	An.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	47.94	799	12	144	380		72		25
Al_2O_3	21.96	216	2	24	190				
Fe_2O_3	2.48	016				16			
FeO	3.42	047				16	6	25	
MgO	6.83	171					30	141	
CaO	12.63	226			190		36		
Na_2O	1.49	024		24					
K_2O	0.19	002	2						
H_2O	2.38								
	99.32								

Constituent.		Norm.				
Quartz		.025	7.50	Q 7.50	Sal 74.07	
Orthoclase		.002	1.11			
Albite		.024	12.58	F 66.51		
Anorthite		.190	52.82			
Diop	Ca	.036	4.18	7.97	P 25.37	Fem 29.08
	Mg	.030	3.00			
	Fe	.006	0.79			
Hyp	Mg	.141	14.10	17.40		
	Fe	.025	3.30			
Magnetite		.016	3.71		3.71	

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 5. Corsase.
Subrang 5. (Persodic.)
(Luzonose?)

TABLE IV.—*Benguet No. 25.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	An.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	58.35	972	186	264	182		98	53	195
Al_2O_3	16.70	164	31	42	91				
Fe_2O_3	4.08	26				26			
FeO	3.28	45				26	9	10	
CaO	7.71	138			91		47		
MgO	3.29	82					38	44	
K_2O	2.87	31	31						
Na_2O	2.62	42		42					
F_2O	1.16								
	100.06								

Constituent.		Norm.				
Quartz		195	11.70	Q 11.70		
Orthoclase		031	17.24		Sal 78.28	
Albite		042	22.01	F 66.25		
Anorthite		091	25.30			
Diopide	Ca	047	5.45			
	Mg	038	3.8	10.44		
	Fe	009	1.19		P 16.16	
Hyp	Mg	044	4.4	5.72		Fem 22.55
	Fe	010	1.32			
Magnetite		026	6.03		M 6.03	
			100.14			

Remarks.—Microscopic examination shows this rock to be somewhat altered so that it is not well adapted to classification according to this system.

Class II. Dosolane.
Subclass I. Dosalone.
Order 4. Austrare.
Rang 4. Tonalase.
Subrang 2. (Sodipotassic.) Harzose.

TABLE V.—*Benguet No. 120.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Am.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	53.92	898	174	282	214		102	33	93
Al_2O_3	18.68	183	29	47	107				
Fe_2O_3	4.27	026				26			
FeO	2.65	037				26	7	4	
MgO	2.93	073					44	29	
CaO	8.85	158			101		51		
Na_2O	2.92	047		47					
K_2O	2.66	029	29						
H_2O+	2.33	148							
H_2O-	.44								
	99.55								

TABLE V.—*Benguet No. 120*—Continued.

Constituent.			Norm.		
Quartz		.093	5.58	Q 5.58	Salic 76.08
Orthoclase		.029	16.12	F 70.50	
Albite		.047	24.63		
Anorth		.107	29.75		
Diop	Ca	.051	5.92	11.30	P 14.73 / Femic 20.76
	Mg	.044	4.40		
	Fe	.007	.98		
Hyp	Mg	.029	2.90	3.43	
	Fe	.004	.53		
Mag		.026	6.03		M 6.03
H_2O		.148	2.77		
			99.55		

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 3. Hessase.
Subrang 2. (Sodipotassic)
(Baguiose?)[5]

[5] The names Luzonose and Baguiose are offered merely as suggestive names.

ILLUSTRATIONS.

PLATE I. Line drawings, 11 figures.

II. Fig. 1, quartz diorite (No. 12) × 15, polarized light; fig. 2, quartz diorite (No. 153) × 15, polarized light.

III. Fig. 1, hypersthene-augite andesite (No. 106) × 9, ordinary light; fig. 2, andesitic tuff (No. 101) × 9, ordinary light.

VI. Fig. 1, andesite porphyry (No. 132) × 9; fig. 2, feldspar porphyry (No. 23) × 9.

V. Fig. 1, foraminiferal limestone (No. 108) × 15 approx.; fig. 2, graywacke (No. 127) × 10.

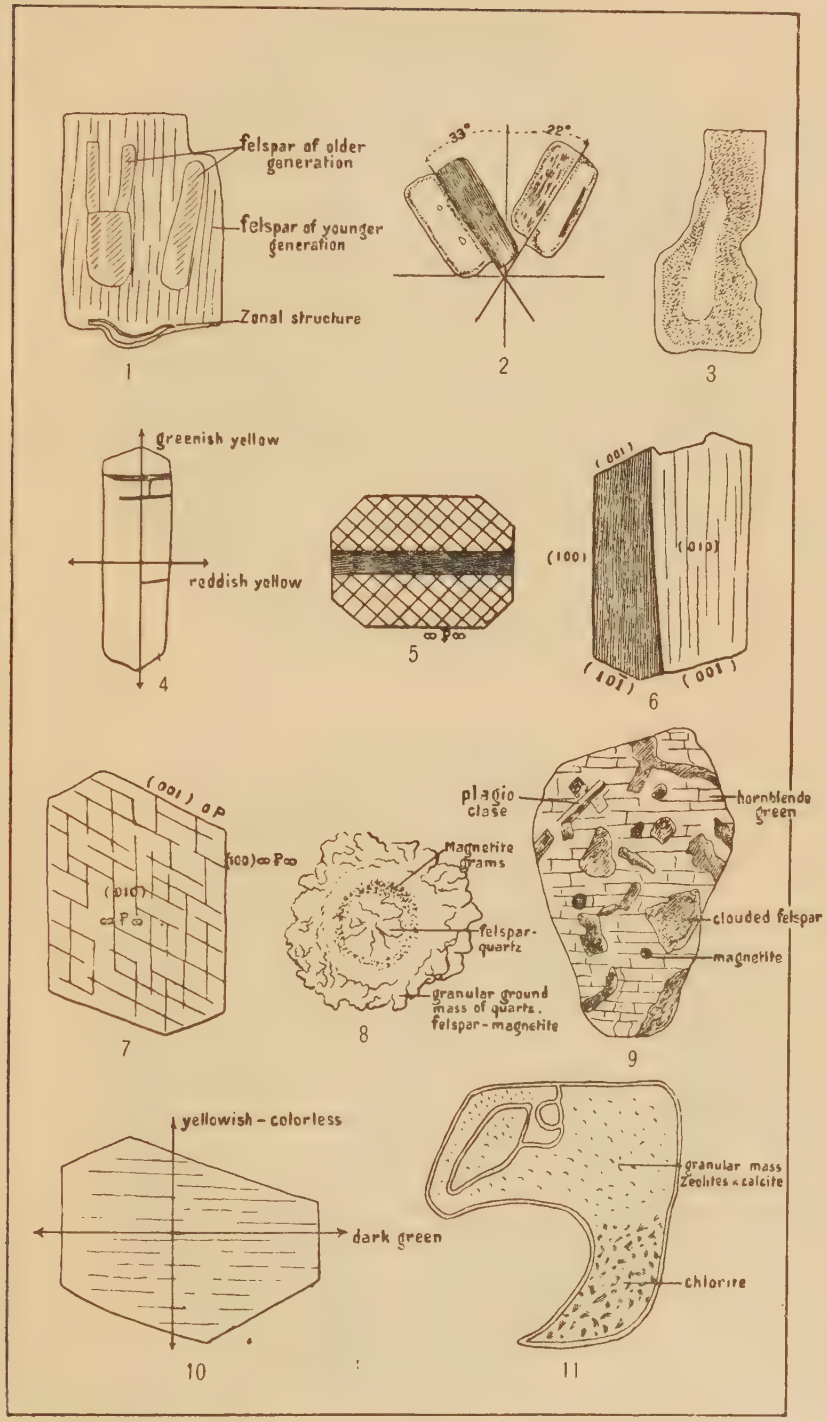
felspar of older generation
felspar of younger generation
Zonal structure
1
33°
28°
2
3
greenish yellow
reddish yellow
4
∞P∞
5
(001)
(100)
(010)
(101)
(100)
6
(001) oP
(100) ∞P∞
(010) ∞P∞
7
plagio clase
hornblende green
Magnetite grams
felspar-quartz
granular ground mass of quartz, felspar-magnetite
8
clouded felspar
magnetite
9
yellowish-colorless
dark green
10
granular mass Zeolites & calcite
chlorite
11

PLATE I.

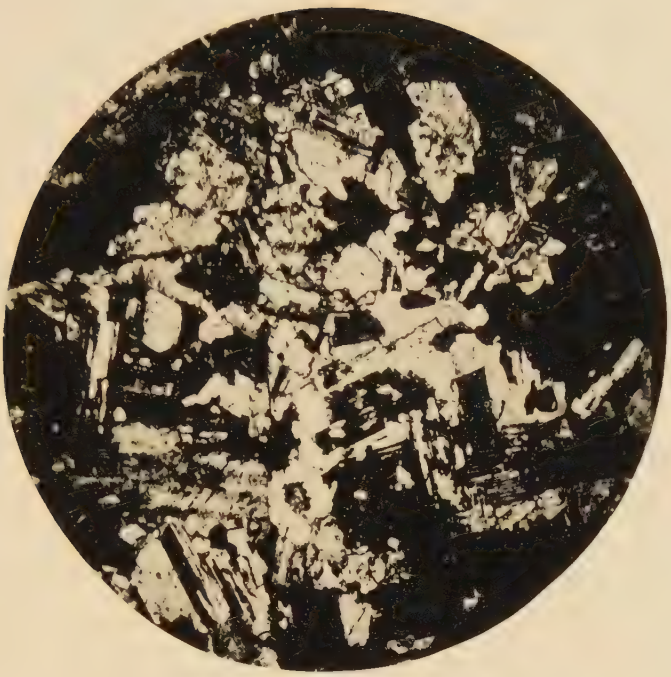

FIG. 1.

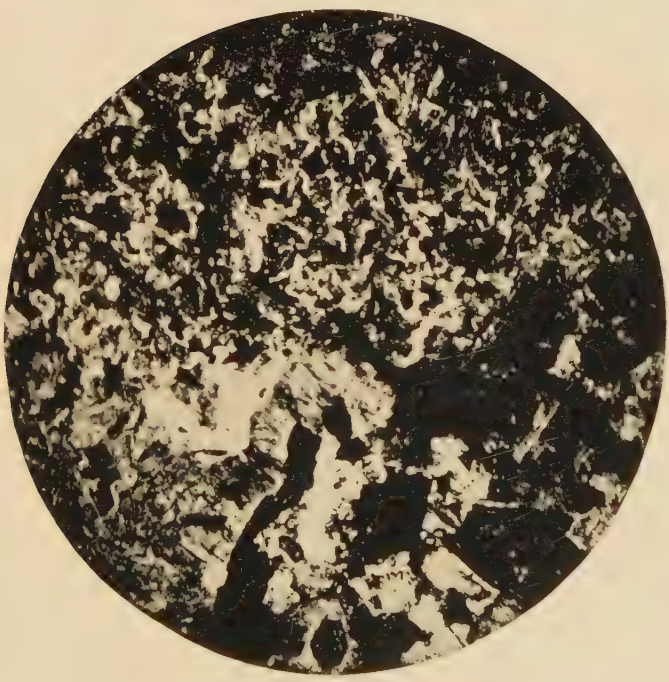

FIG. 2

PLATE II.

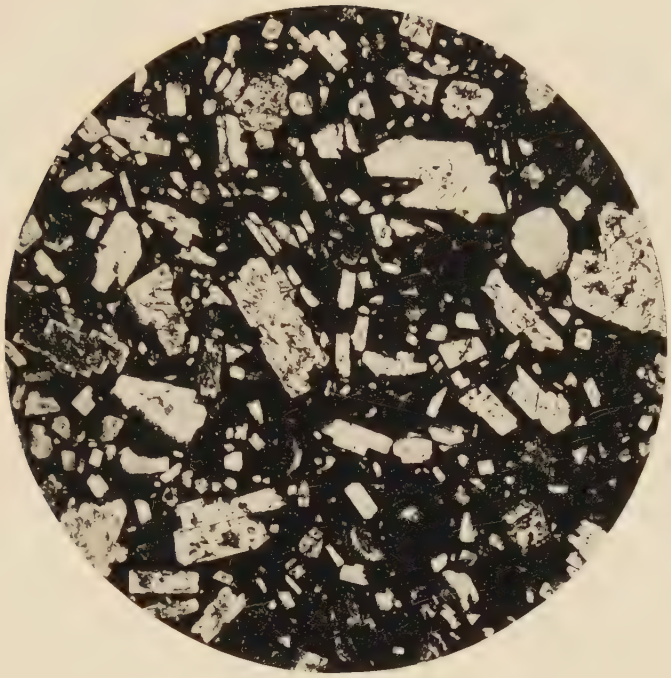

FIG. 1.

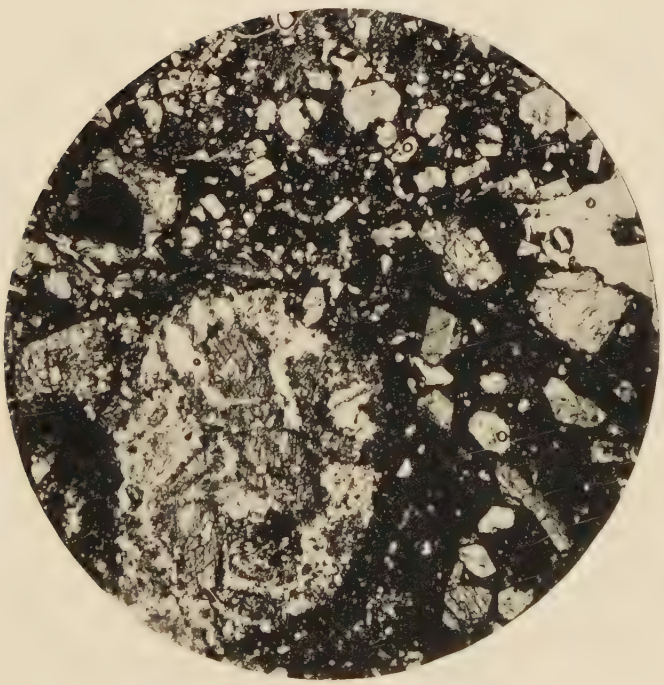

FIG. 2

PLATE III.

FIG. 1.

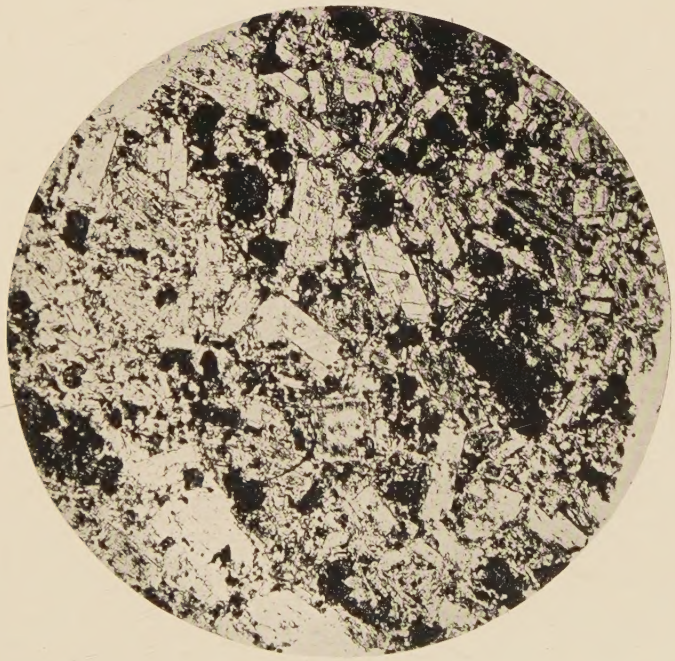

FIG. 2.

PLATE IV.

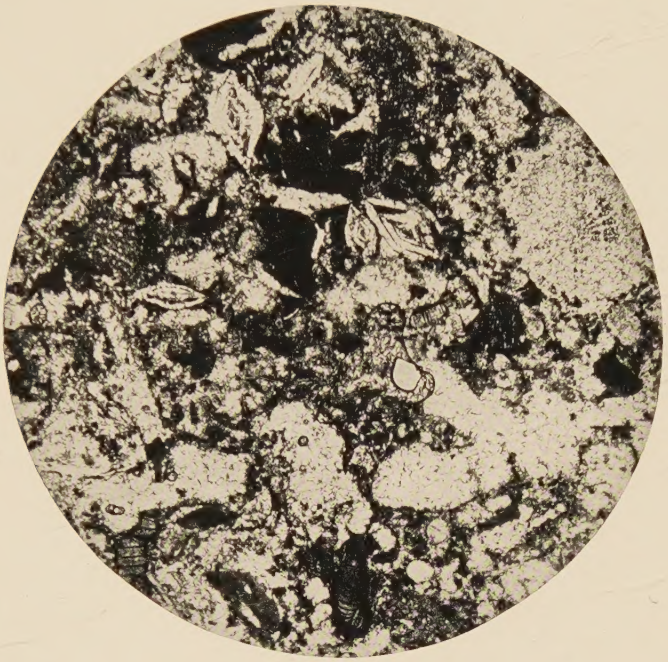

FIG. 1.

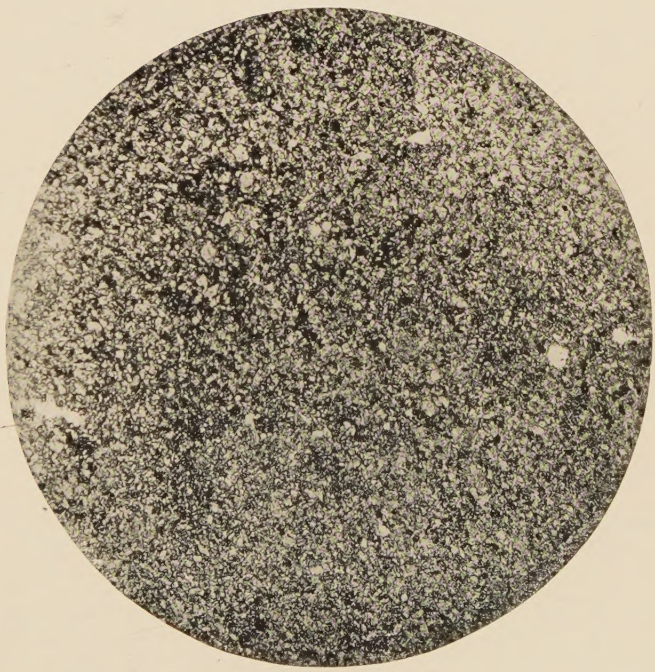

FIG. 2.

PLATE V.

A First Course in Physics. By Robert Andrews Millikan, Ph. D., and Henry Gordon Gale, Ph. D. Cloth. Pp. VIII+488. Price, $1.25. Boston: Ginn & Company, 1906.

This book is written as if it were the intention to make the laboratory work, which is given only in footnote references to a manual, teach the text rather than for the text to teach the laboratory work. Unlike many elementary physics the subject matter is presented in a logical and a thoroughly comprehensible manner. A distinctive feature is the excellence of the portraits and illustrations which are "in the fullest possible sense educative."

A. J. C.